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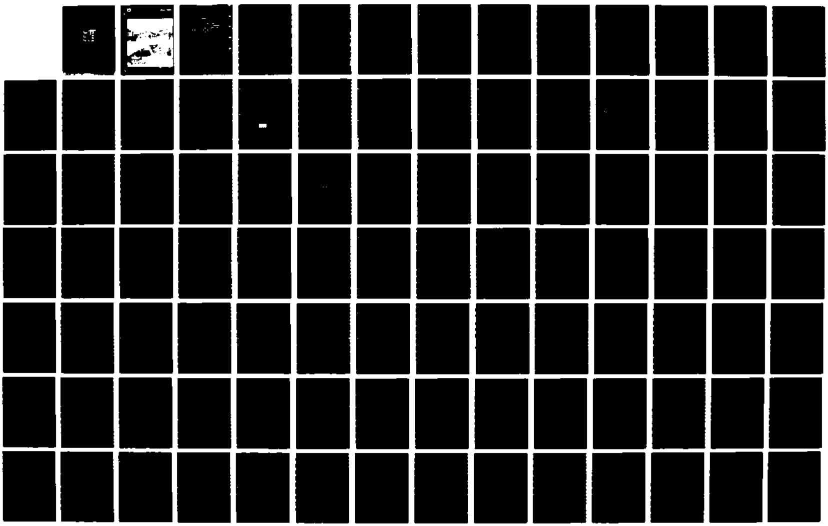

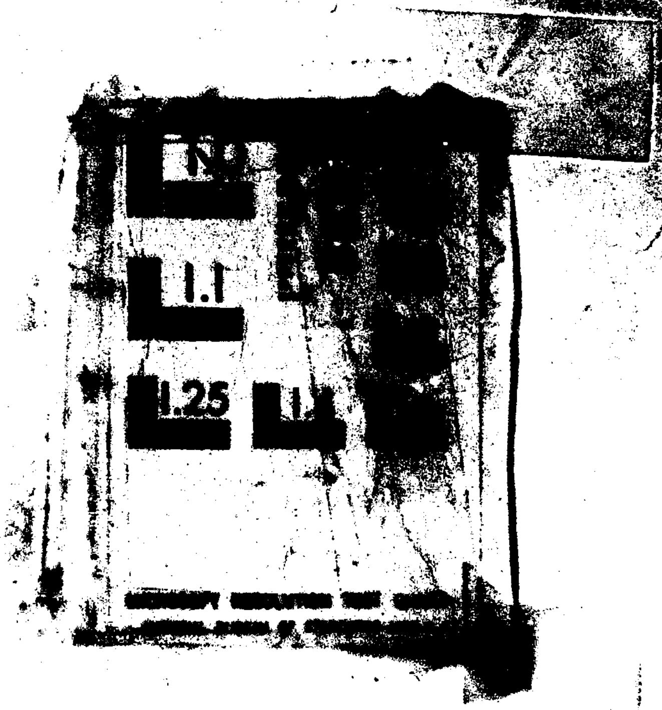
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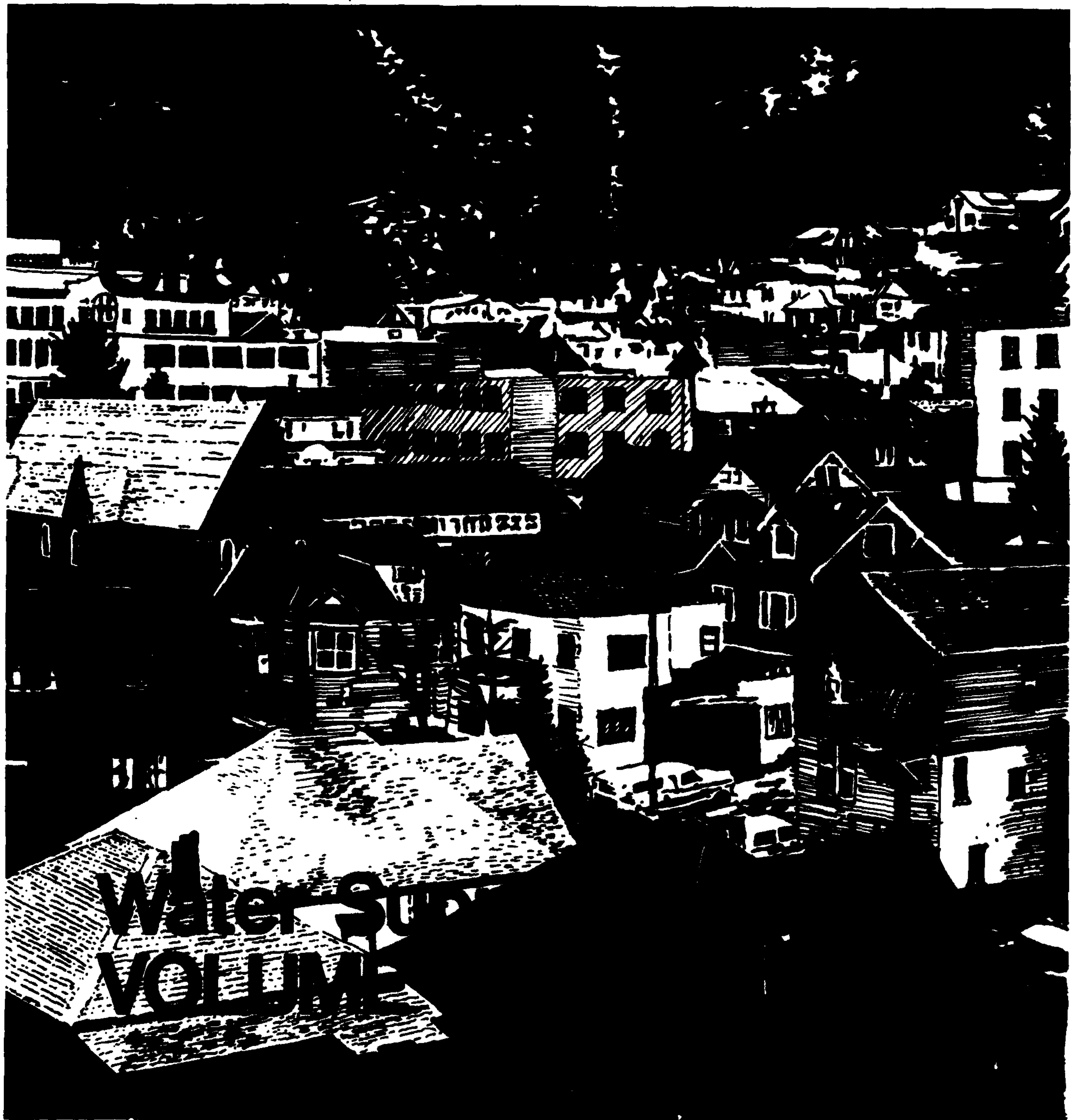

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Fargo-Moorhead Urban Study is a cooperative Federal, State and local planning effort aimed at developing viable solutions to water and related land resource problems, needs and concerns for 1980-2030.

The summary report contains a brief, non-technical overview. Readers desiring additonal detailed information should review the appropriate technical appendixes.

In 1981, the city of Fargo began disposing its municipal solid waste in a

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sanitary landfill located northwest of the city, and adjacent to a 157-acre parcel of land that had served as the landfill from the early 1950's to 1981. Recent pumping tests suggest that the new landfill as well as the west edge of the old Fargo landfill overlie the West Fargo Aquifer. This aquifer supplies water to the cities of West Fargo and Riverside, North Dakota. The purpose of this study is to gather initial data to be used in the assessment of potential health hazards resulting from the contamination of subsurface water supplies. Key words: → front of 1473

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FARGO-MOORHEAD URBAN STUDY

WATER SUPPLY APPENDIX

VOLUME III

PHASE 2, ATTACHMENT A
GEOCHEMICAL INVESTIGATION
OF THE
OLD FARGO LANDFILL

St. Paul District, Corps of Engineers
1135 U.S. Post Office and Custom House
St. Paul, Minnesota 55101-1479

MAY 1985

PREFACE

The Fargo-Moorhead Urban Study was sponsored by the St. Paul District, Corps of Engineers, as a cooperative effort of local, State, and Federal agencies. The results of this study are contained within the following documents:

- Summary Report
- Background Information Appendix
- Water Supply Appendix (3 Volumes)
- Water Conservation Appendix
- Energy Conservation Appendix
- Flood Control Appendix
- Fargo-Moorhead Water Resource Data Management System Appendix (3 Volumes)

The Summary Report contains a brief, non-technical overview of the results of the overall study. Only readers desiring additional detailed information should review the appropriate technical appendixes.

ACKNOWLEDGEMENTS

The author wishes to thank the U.S. Army Corps of Engineers and North Dakota State University, Civil Engineering Department for the funds necessary to carry out this project. Help, in the form of laboratory services, provided by the North Dakota State Department of Health is gratefully acknowledged.

Special appreciation is extended to Tim Safford and Carol Reifschneider of the Department of Civil Engineering, North Dakota State University for their assistance during this project.

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FIGURES, GRAPHS, and TABLES

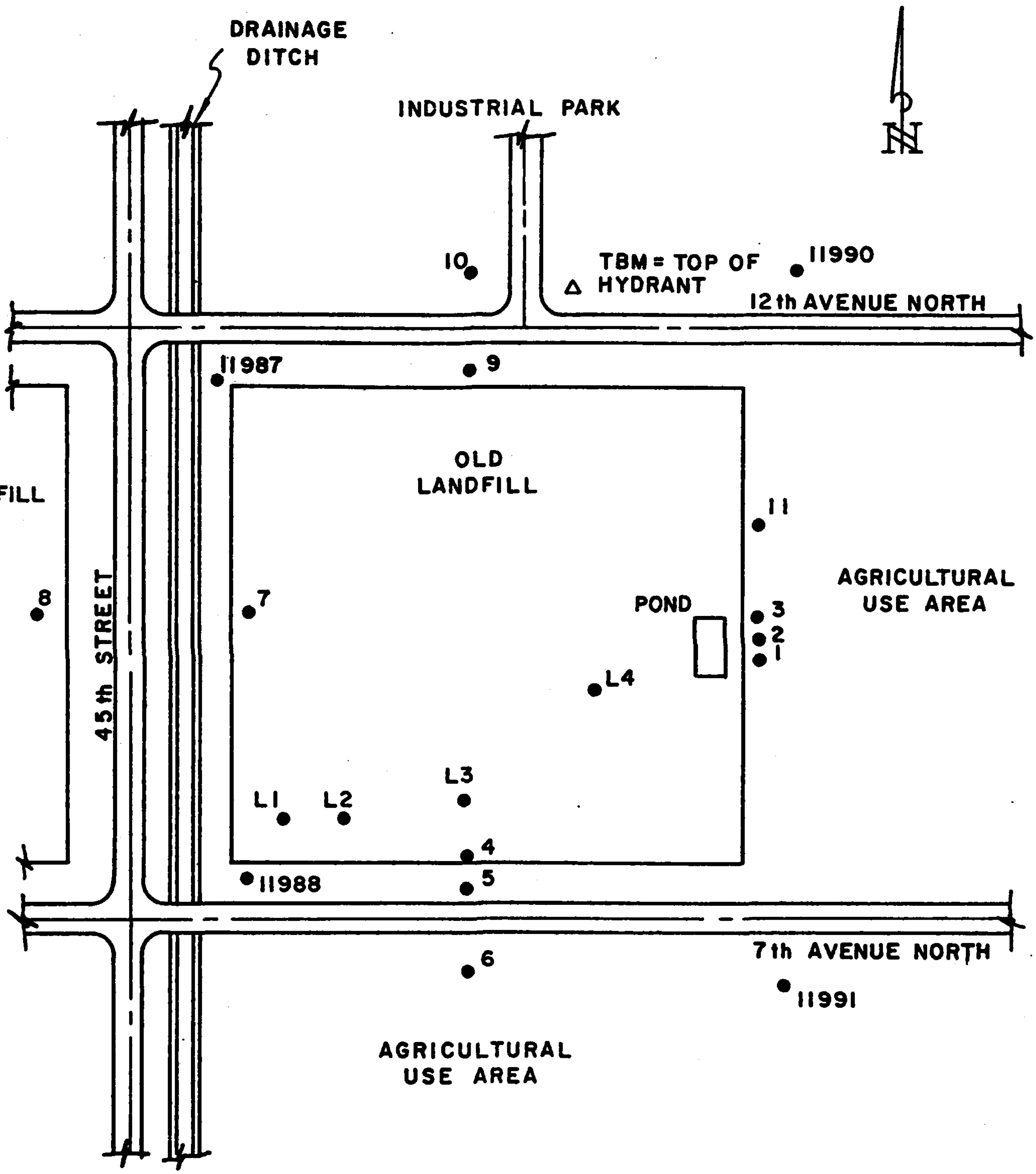
FIGURES, GRAPHS, and TABLES (Cont)

INTRODUCTION

In 1981, the city of Fargo, North Dakota, began disposing of its municipal solid waste in a new sanitary landfill, a 160-acre tract of land located northwest of the city in an industrial/agricultural area. Just east of, and adjacent to, the present Fargo sanitary landfill is a 157-acre parcel of land that had served as the city's municipal landfill from the early 1950's until 1981 (Figure 1).

Recent pumping tests conducted by the North Dakota State Water Commission suggest that the new landfill as well as the west edge of the old Fargo landfill overlie the West Fargo Aquifer, a Type I aquifer. This aquifer supplies water to the cities of West Fargo and Riverside, North Dakota. In addition, the Cass Rural Water Users Association services its customers in the North Dakota communities of Briarwood, Frontier, Mapleton, North River, and Reile's Acres with water also drawn from the West Fargo Aquifer. A study to determine alternative long-term uses for the old Fargo landfill was conducted by the North Dakota State University Civil Engineering Department for the city of Fargo in the summer of 1981. Samples of leachate taken at that time showed potential for contamination by trace metals and other pollutants. Concern has since been expressed at the possibility of groundwater contamination by the leachate.

As a result of that study, the U.S. Army Corps of Engineers contracted with Dr. D.M. Griffin Jr. of the North Dakota State University Civil Engineering Department, in the fall of 1982, to further investigate the possibility of groundwater contamination due to leachate migration from the old Fargo landfill. The



LOCATION OF WELL SITES AT OLD FARGO LANDFILL

FIGURE 1

purpose of this study was to gather initial data to be used in the assessment of potential health hazards resulting from the contamination of subsurface water supplies.

Data collected from regular monitoring of 15 observation wells located on and adjacent to the old landfill site included: groundwater-level fluctuations, groundwater conductivities, and groundwater temperatures. These data along with the precipitation records provided by the National Weather Service of Fargo, North Dakota, were used to provide information on the quantity and movement of leachate at the old Fargo landfill. Chemical analysis of leachate samples by the North Dakota State Department of Health and North Dakota State University provided information on leachate quality. The specific objectives of the study were:

1) Determine net leachate production based on a water budget for the old Fargo landfill.
2) Determine if leachate is escaping from the old Fargo landfill and, if so the mechanism or mechanisms of escape and the direction of movement.
3) Identify any leachate contaminants that pose threats (present or potential) to the environment and/or public health.
4) Identify specific elements of the natural and human environment that are or could be threatened should the groundwater be contaminated.

MATERIALS AND METHODS

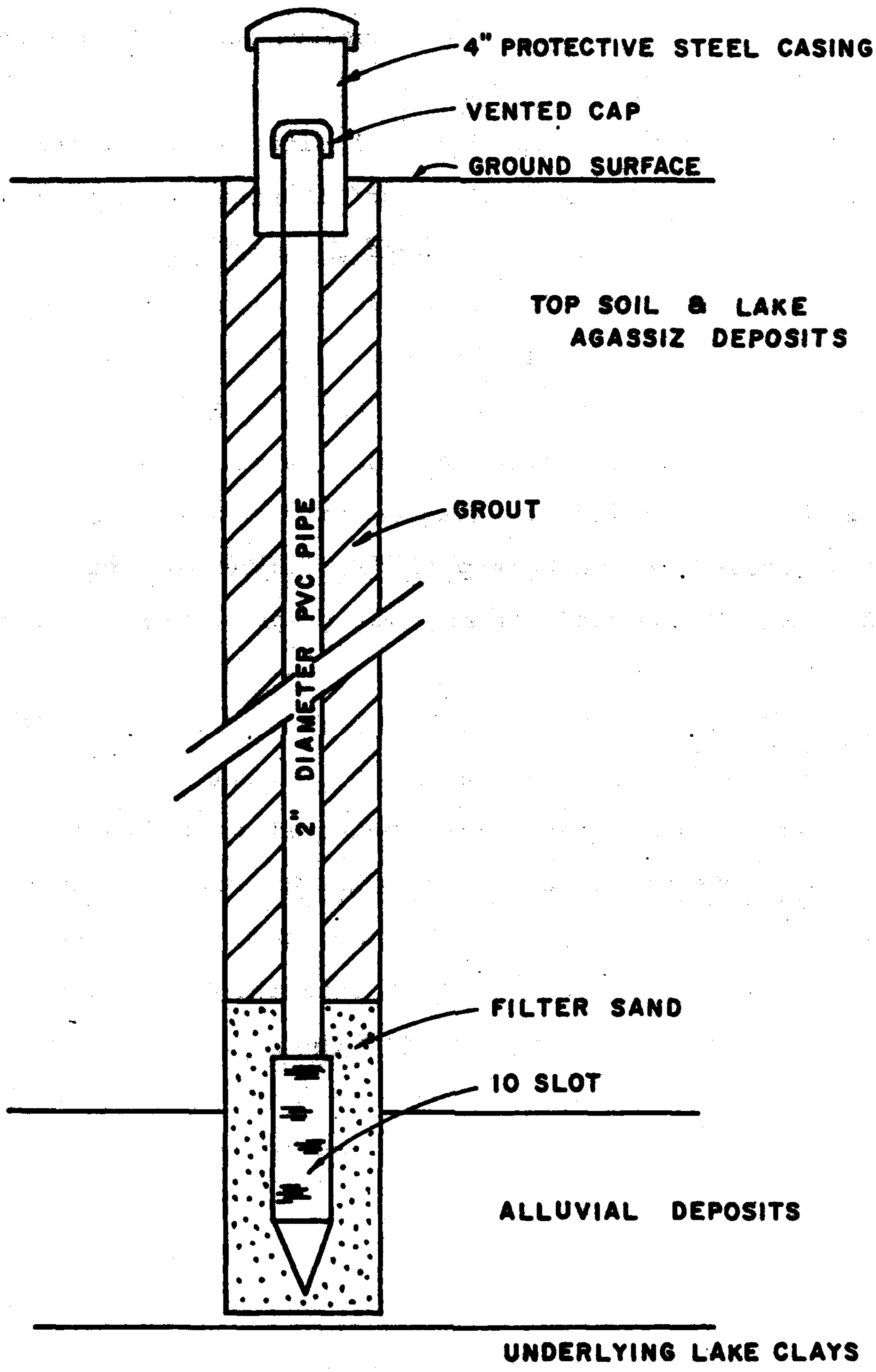
Well Construction

Twin City Testing and Engineering Laboratory, Inc., Fargo, North Dakota, was contracted in December 1982 to install 11 observation wells adjacent to the old Fargo landfill. Work was completed in January 1983.

Soil samples were taken at eight of the observation well sites. The test borings were performed according to the procedure described by ASTM: D1586-67. Soil sampling and classification were performed in accordance with ASTM: D2488-69.

The 11 observation wells, ranging in depth from 15 to 100 feet, consisted of 5- to 10-foot lengths of 2-inch PVC screens placed at the bottom of each of the borings. Two-inch, Schedule-40 PVC extended above the screens to a distance of 2 to 3 feet above ground level (Figure 2). The screens were wrapped with cheesecloth and then backfilled with 45 to 55mm-diameter filter sand. Grout, three parts cement to two parts bentonite, was used to backfill the borings from the filter sand to the ground surface. Four-inch diameter steel casings were placed over the PVC standpipes and capped, for protection.

In addition to the 11 newly installed observation wells, four observation wells installed on the landfill in the summer of 1981 were included in the study for observation and sampling purposes. The four wells were put in place after excavations were made by backhoe. The well casing and screen consisted of 6-inch PVC pipe. The screen, a series of 1/2-inch holes drilled at the bottom of the casing, was backfilled with 2-inch diameter rock



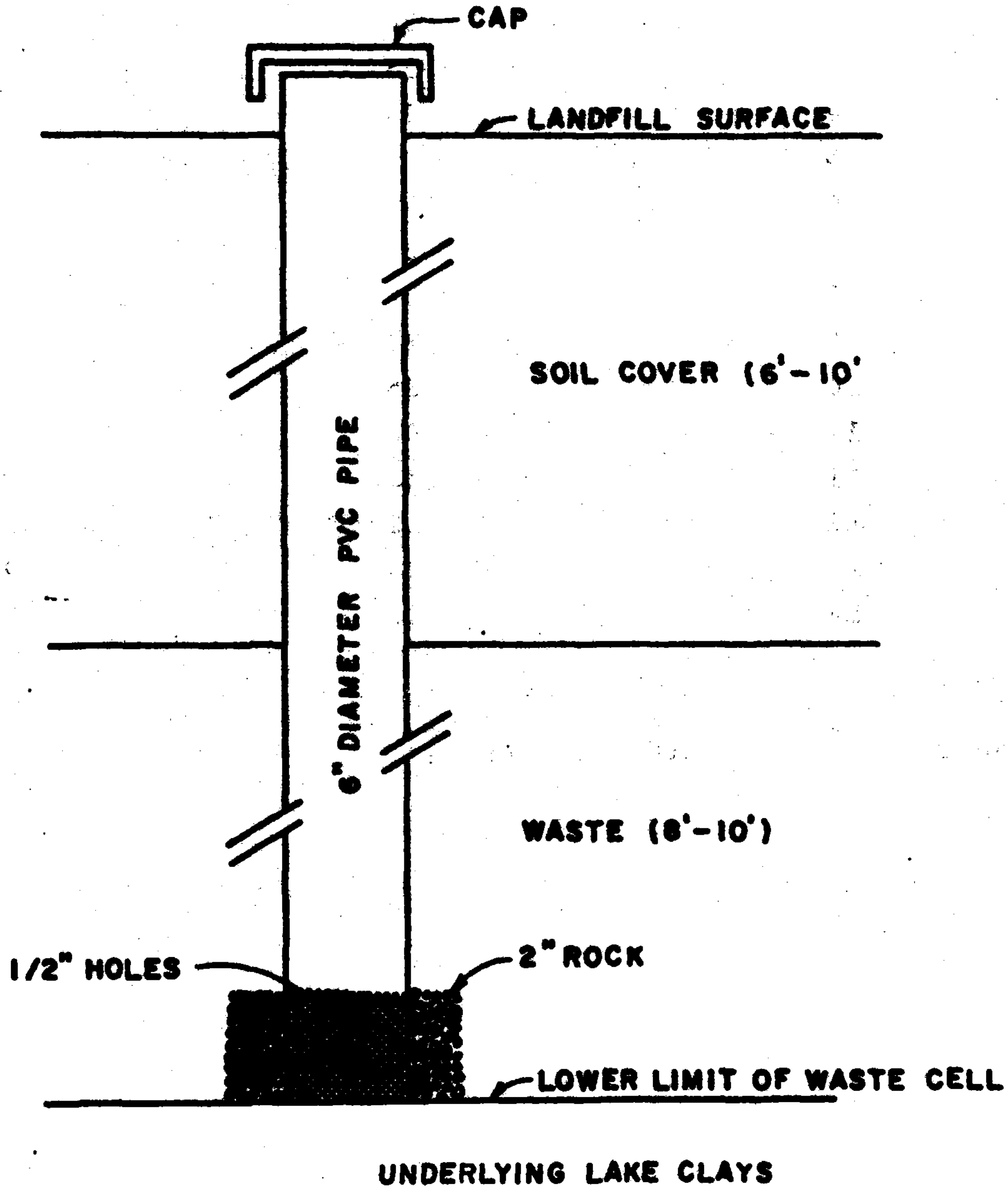
DETAIL OF NEW PIEZOMETER
FIGURE 2

(Figure 3). The remainder of the excavation was backfilled with the removed material. A list of the observation wells and their respective depths is given in Table 1.

A survey of the old Fargo landfill site was conducted with the use of a standard level. The landfill site was staked on a 400-foot (north to south) by 200-foot (east to west) grid. Ground surface elevations at all stations were determined in relation to a bench mark (fire hydrant) located just beyond the northeast corner of the landfill. The bench mark was assigned an elevation of 898.17 feet above mean sea level. Elevations for all wells were determined in relation to the bench mark. The elevations correspond to the top of the inside well casing. A topographic map of the landfill site was prepared from the survey (Figure 4).

Monitoring and Sampling Procedures

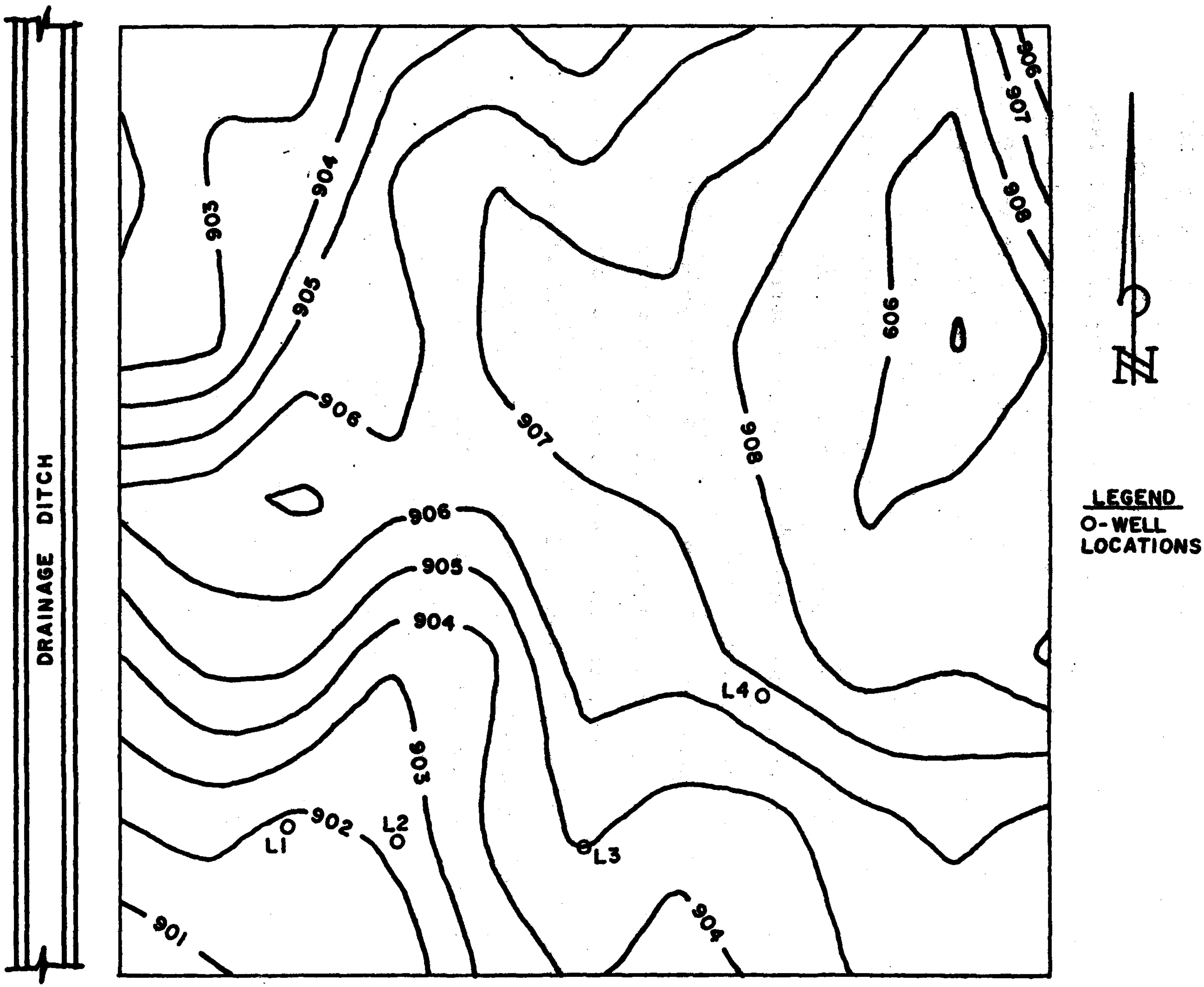
Water table fluctuations were monitored on a weekly basis beginning in September 1982. Initially, groundwater elevations from the four older wells were recorded. Upon their completion, the 11 newer wells were incorporated into the monitoring schedule. Groundwater temperature profiles, in each of the observation wells, were recorded on a weekly basis beginning in March 1983. Measurement of electrical conductivity profiles was initiated in June 1983 and performed weekly. Weekly monitoring of the wells was discontinued in July 1983 at which time groundwater surface elevation, temperature, and conductivity were recorded once a month prior to groundwater sampling.



DETAIL OF OBSERVATION WELLS INSTALLED IN 1981
FIGURE 3

Well Number	Depth to Bottom of Screen (feet)	Length of Screen (feet)
1	50	5
2	30	5
3	23	10
4	25	5
5	30	5
6	35	5
7	35	5
8	35	5
9	30	5
10	35	5
11	100	5
L1	15	2-3
L2	15	2-3
L3	20	2-3
L4	15	2-3

TABLE 1. Observation Well Depths



TOPOGRAPHY OF OLD FARGO LANDFILL (CONTOUR INTERVAL = 1 FOOT)

FIGURE 4

Groundwater analysis was performed by both the North Dakota State University Civil Engineering Sanitary Laboratory and the North Dakota State Department of Health, Public Health Laboratory. Samples were withdrawn from each of the observation wells during three consecutive months: June 14-15, July 19 and 26, and August 22-23, 1983. The physical, organic, and inorganic (metallic and nonmetallic) parameters analyzed are given in Table 2. To obtain a representatiave sample of the groundwater the observation wells were purged of a volume of water equal to the amount standing in the casing.[19] Purging was performed from 2 to 7 days prior to sampling.

Samples designated for mineral analysis were collected in Nalgene polyethylene, 1-liter, collapsible containers. Samples designated for nitrate and total dissolved phosphate analysis were collected in Nalgene polyethylene, 175-milliliter bottles and preserved with sulfuric acid. Dissolved orthophosphate analysis was performed on samples collected in Nalgene polyethylene, 175-milliliter bottles. The above samples, with the exception of those designated for mineral analysis, were filtered through glass-fiber filters shortly after collection. Groundwater samples obtained for trace metal analysis were collected in Nalgene polyethylene, 175-milliliter bottles and preserved with nitric acid. Samples to be used for herbicide and pesticide analyses were collected in 1-quart Mason glass jars. All of the sample containers were supplied by the North Dakota State Health Laboratory and prepared in accordance with their "Quality Assurance Manual," 1982 (Revision 0).

INORGANIC ANALYSES

Conductivity
Total Dissolved Solids
pH
Total Alkalinity
Total Hardness
Fluoride
Chloride
Ammonia
Nitrate
Total Kjeldahl Nitrogen
Sulfate
Total and Ortho Phosphate
Bicarbonate
Carbonate
Calcium
Magnesium
Manganese
Potassium
Sodium
Sodium Adsorption Ratio
Iron
Arsenic
Barium
Cadmium
Chromium
Copper
Lead
Selenium
Silver
Zinc
Chemical Oxygen Demand

ORGANIC ANALYSES

Endrin
Lindane
Methoxychlor
Toxaphene

2, 4 - dichlorophenoxyacetic acid (2,4-D)
2-(2,4,5-trichlorophenoxy) propionic acid Silvex (2,4,5-TP)

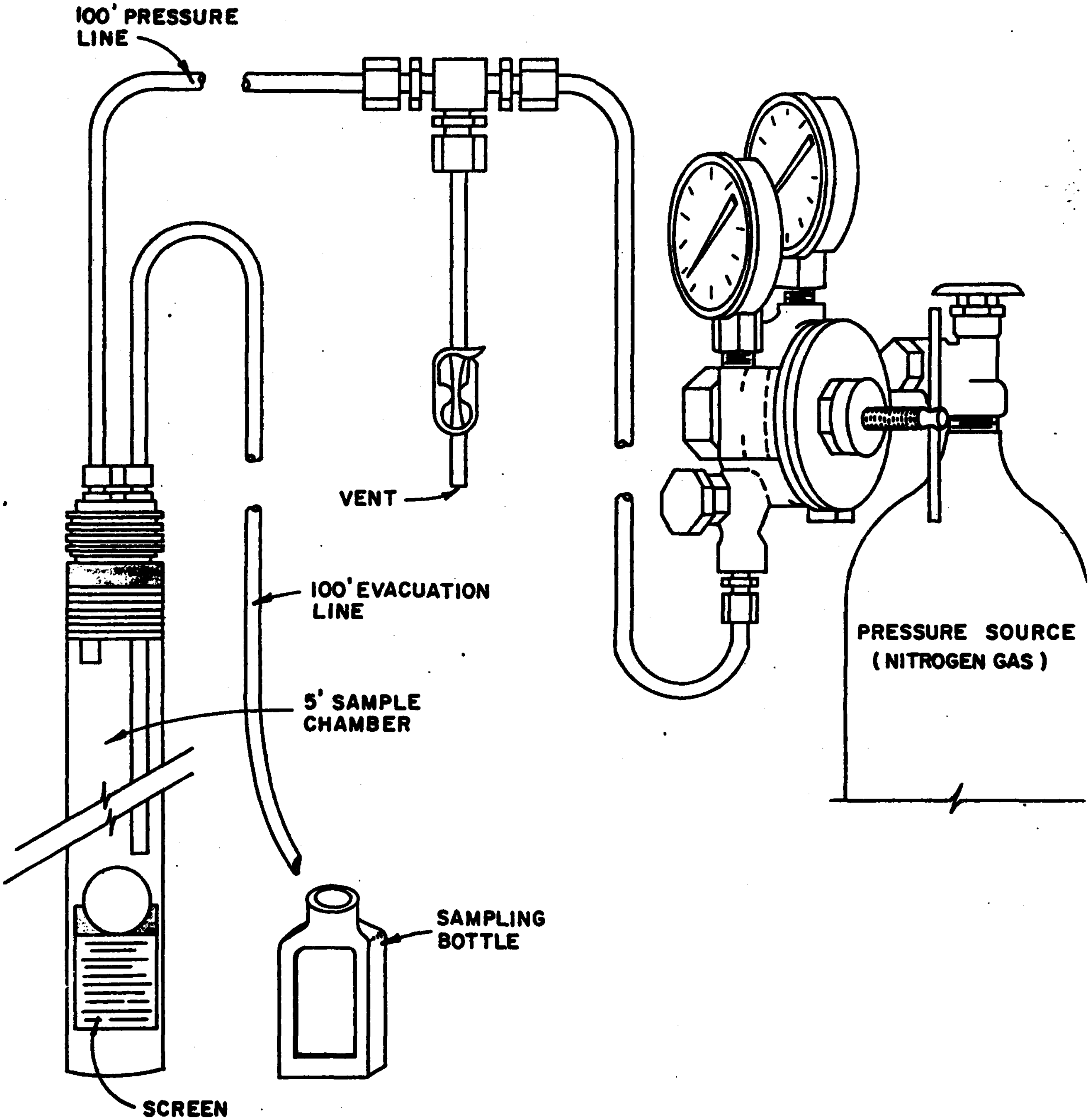
TABLE 2. Listing of Inorganic and Organic Parameters Analyzed.

Samples were stored on ice in portable, insulated coolers while in the field. While being stored in the North Dakota State University Sanitary Laboratory awaiting shipment to the North Dakota State Health Laboratory the collected groundwater samples were refrigerated at 4 degrees C. The North Dakota State Health Laboratory received all samples within 72 hours after collection. The samples were again stored on ice in portable, insulated coolers while enroute to the North Dakota State Health Laboratory.

Groundwater samples were withdrawn from the wells using a Timco gas-lift sampler (Figure 5). The sampling device consisted of a 5-foot long sample chamber constructed of 1.66-inch (O.D.) PVC. The pressure and evacuation lines consisted of two, 100-foot lengths of 3/16-inch (I.D.) Tygon tubing. A portable nitrogen gas tank provided the pressure source.

The standing groundwater in each of the wells was mixed by lowering the sampling device to the bottom of the well screen. The outside of the sample chamber was rinsed with distilled water prior to lowering it into the well. In addition to rinsing the outside of the sample chamber, the initial samples from each of the wells were purged to prevent sample contamination between the observation wells. The sample containers were filled to the top when sufficient sample was present in the well. In all instances, the containers were capped tightly. A square of tin foil was placed over the mouth of the Mason jars before the lids were placed and secured.

Water table elevations were measured with a 100-foot chalk-covered metal tape. Groundwater temperatures were measured with



TIMCO GAS-LIFT SAMPLER

FIGURE 5

both a Yellow Springs Tele-Thermometer and a Yellow Springs S-C-T Meter, model 33. A 50-foot probe was lowered directly into the well and temperatures recorded at depth intervals of 1 meter, beginning at the water surface. Conductivity, in umhos/cm, was measured in a similar manner using the same Yellow Springs S-C-T Meter, model 33. Calibration of the meter was checked against a standard 0.01m KCl solution. The probe was rinsed with distilled water between well measurements.

Groundwater pH was measured for each of the observation wells at the time of sampling. The measurement was made with the use of portable Hach Digital pH Meter, model 19000. The pH meter was calibrated according to manufacturer's instruction prior to each sampling session. The pH probe was rinsed with distilled water between measurements.

Chemical Analyses

Complete chemical analysis of all groundwater samples was performed by the North Dakota State Department of Health, Public Health Laboratory. The organic and inorganic chemical parameters and the physical parameters determined by the North Dakota State Health Laboratory are listed in Table 2. Methods used in the identification of organic and inorganic constituents of the groundwater samples are given in Appendix I.

Atomic absorption spectrophotometry was used in the determination of: Ca, Fe, K, Mg, Mn, Na, and trace metals. The organic pesticide and herbicide concentrations were measured by gas chromatographic techniques.

Laboratory methodology used by the North Dakota State Univer-

sity Sanitary Laboratory was taken from "Standard Methods for the Examination of Water and Wastewater," 14th Edition (1975). In addition to the measurement of pH and conductivity in the field, laboratory analyses of the collected groundwater samples included alkalinity, 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), and hardness.

COD determinations were made on filtered and unfiltered groundwater samples using the dichromate-reflux method. Samples were passed through glass-fiber filters. A pH meter was used to monitor the end points of 4.5 and 8.1 for total and pher olphthalein alkalinities, respectively; analysis was performed on 25 ml samples decanted from the settled groundwater samples. Five milliliter samples taken from the supernatant of the settled groundwater samples were diluted to 50ml for the determination of total and calcium hardness. BOD_5 was determined by the static bottle test.

Water Balance Methods

The landfill water budget was determined using a modified water balance method.[1] All precipitation and temperature records were obtained from the Fargo North Dakota, office of the National Weather Service.

PHYSICAL CONDITIONS

Site Location and Description

The old Fargo landfill is located one-half mile west of Interstate 29. It lies between 12th Avenue and 7th Avenue North and is bordered on the west by 45th Street. The 157-acre tract

of land is in the NW1/4 Sec. 3, T. 139N., R49W.

Since the early 1950's, most of the solid waste from Fargo has been buried at this location. The landfill site was closed in 1981. A 160-acre parcel of land just to the west of the old landfill is currently being used for the disposal of the city's solid waste.

Local Geology[2]

All of Cass County is covered by glacial drift deposited as the last ice sheet receded from the area in late Wisconsin time. This includes the two Fargo landfill sites. The thickness of the drift (including glacial Lake Agassiz deposits) ranges from 132 to 447 feet, with an average thickness of 250 feet. The surface geology in the area of the old Fargo landfill is largely the result of lake-plain deposits from glacial Lake Agassiz. The deposits consist almost entirely of silt and clay. The silt unit overlies and rests disconformably upon the clay unit. Distinction between the two units is based on texture or color, the silt unit appearing yellowish brown to yellowish gray, and the clay unit appearing olive gray to dark greenish gray. "Locally the 'silt' unit may consist entirely of clay or sand."[2] The thickness of the silt unit ranges from 10 to 50 feet. The clay unit ranges in thickness from 0 to 80 feet and rests unconformably upon till and associated deposits. Sand deposits of fluvial origin often underlie or are associated with the silt unit.

The old Fargo landfill is situated above the east edge of the West Fargo aquifer and west of the Fargo aquifer. Both aquifers are described as buried outwash, a major subsurface unit within

Cass County.

The West Fargo aquifer, as defined in 1968, underlies an area of approximately 110 square miles. The aquifer extends in a north-south direction with a range in thickness from 0 to as much as 140 feet. The average thickness of the aquifer is about 60 feet. It is a confined, artesian aquifer overlain by glacial till and lake deposits. The combined thickness of the two upper confining beds ranges from 80 to 170 feet. Recharge of the West Fargo aquifer is presumed to occur by lateral movement of water through surrounding till and associated deposits and by downward percolation of water from the water table in the silt unit of the Lake Agassiz deposits.

With an average thickness of 45 feet, the Fargo aquifer ranges in thickness from 0 to 160 feet. The aquifer underlies an area of 10 or more square miles. Like the West Fargo aquifer, the upper confining beds are of glacial till and lake deposits. The average depth of the overlying materials is about 130 feet. Recharge of the Fargo aquifer is thought to occur through the lateral movement of water from the surrounding till and by downward percolation of water through the overlying deposits.

Soil Description

Soil samples were collected for 8 of the 11 newly installed observation wells. In addition, test hole records and soil sample descriptions were obtained from the North Dakota State Water Commission[3] on 2 observation wells and 2 test holes located in the vicinity of the old Fargo landfill. Locations of the 2 observations wells and 2 test holes are given in Figure 1 and

are denoted by numbers 11987, 11988, 11990, and 11991 respectively. A report of a 1979 soil investigation performed on the site of the current Fargo landfill was also obtained.[4]

In general, the waste in the old Fargo landfill was placed in one lift with an average compacted thickness of approximately 8 feet.[5] The garbage layer was covered with fill material obtained on the site. The depth of cover ranged from 6 to 10 feet. Mechanical analysis performed during an earlier study determined that the surface fill material was silty clay with a clay fraction upwards of 50 percent.[5] The soil investigation accompanying the 11 test borings for this study[6] revealed a surface layer of fill in borings 4 through 10. The depth of fill varied from 2 to 9 feet in thickness. The garbage layer was only encountered in borings 4 and 9. The fill layer, or in the cases of borings 4 and 9, the garbage layer was underlain by a brown and gray mottled clay. This clay layer reached an average depth of 16 3/4 feet and was followed by a grey clay layer. Comparable units were identified in the drilling logs and soil descriptions from the North Dakota State Water Commission and the 1979 soil investigation of the current landfill site. Both units are considered Lake Agassiz deposits.

A prominent feature of the three separate drilling records was a silty sand-sand layer encountered at nearly all drilling sites. The test boring logs for the 11 observation wells placed adjacent to the old Fargo landfill revealed a silty sand layer that varied in thickness from a maximum of 10 feet to a minimum of 2 feet. There appeared to be a slight increase in thickness in the southeast direction. The sand deposits appeared to

underlie the brown and gray mottled clay layer in nearly all borings. The upper profile of the sand layer ranged from 13 to 18-1/2 feet from the landfill surface and showed a slight increase in depth in the direction of the northeast corner of the landfill (Figures 6, 7, 8, and 9). In all but one of the borings (boring 4), the silty sand layer was underlain by gray clay. Test hole records from the North Dakota State Water Commission indicate that the gray (lake clay) bed continues to an average depth of 85-1/2 feet from the landfill surface. This was confirmed by the test boring logs from observation well 11.

Water Balance

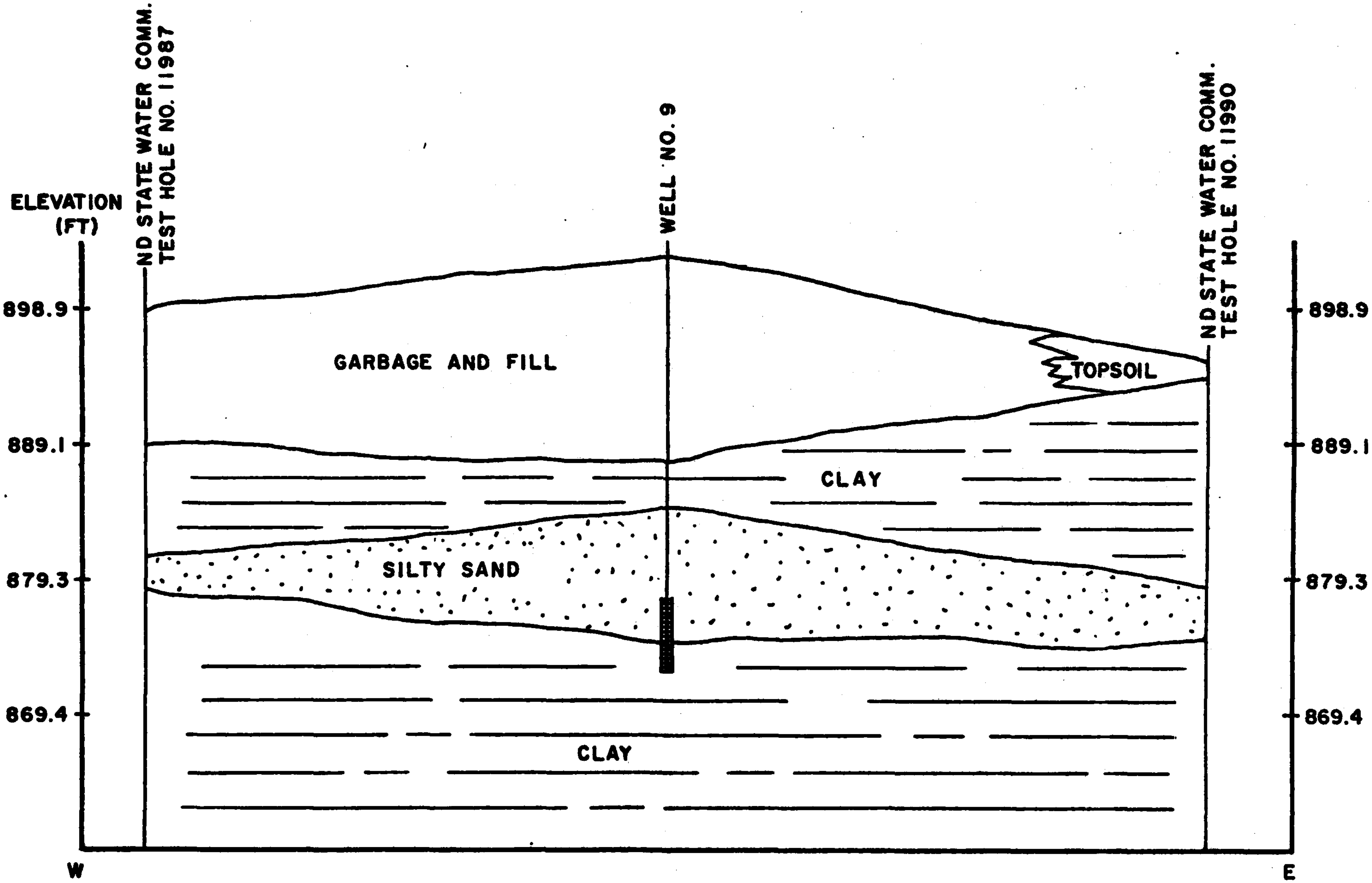
One objective of this study was to determine the net leachate production from the old Fargo landfill. Recent literature indicates that a modified form of the water balance is a satisfactory method of predicting leachate production at a landfill site.[7]

Briefly, leachate is water that has percolated through solid waste and enroute has picked up dissolved and/or particulate material. Many of the materials found in solid waste are water soluble, while others become soluble after the leachate acts upon them. In addition, there are many soluble products from the biodegradation of solid waste. Should this leachate come in contact with ground or surface waters, contamination will occur.

The basic equation for determining the anticipated amount of percolation and corresponding leachate production at a specific landfill site is as follows:

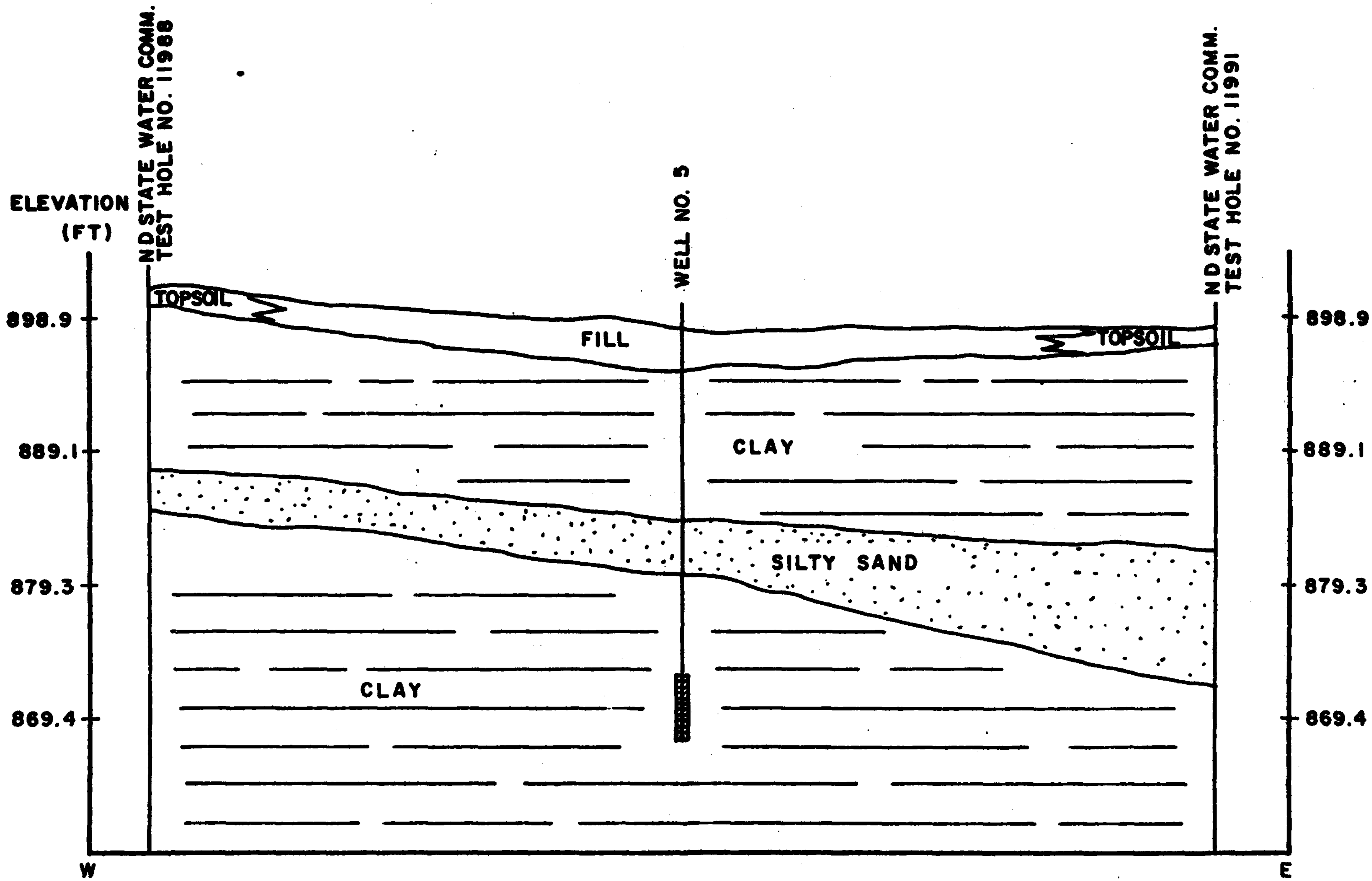
$$PERC = P - R - AET - S$$

in which PERC = moisture percolated to the solid waste; P = pre-



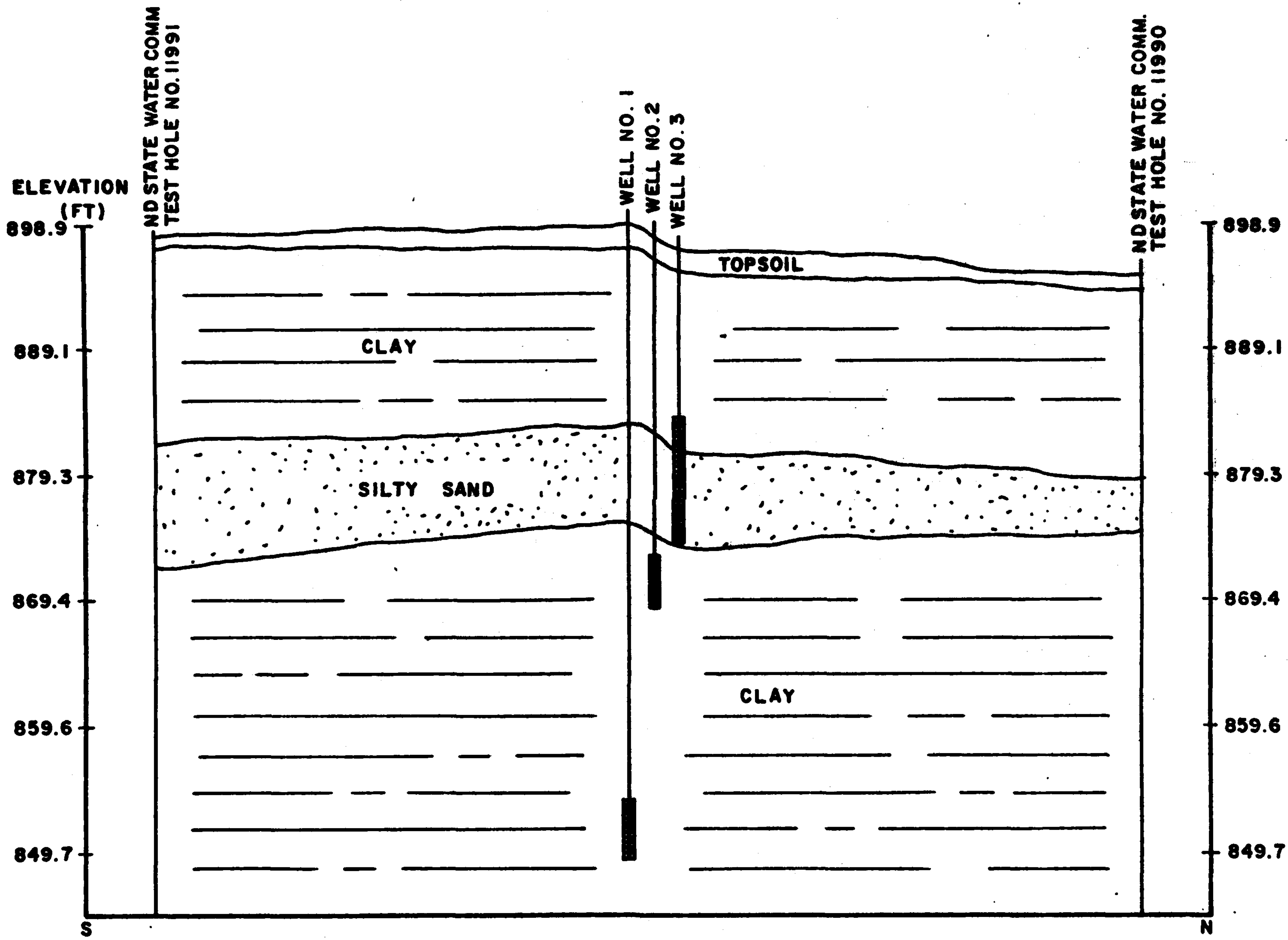
EAST-WEST CROSS-SECTION ALONG NORTH BORDER OF OLD FARGO LANDFILL

FIGURE 6



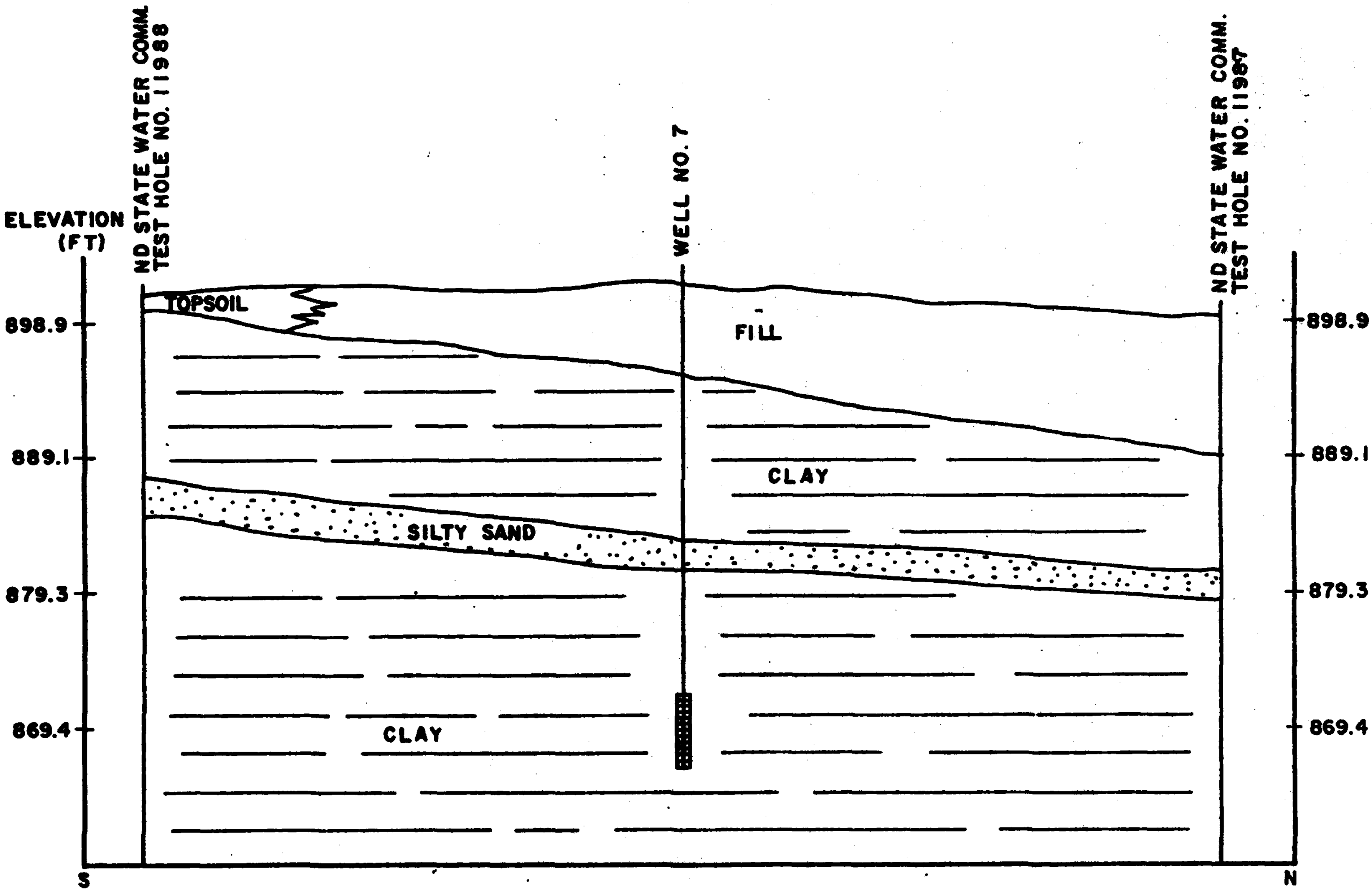
EAST-WEST CROSS-SECTION ALONG SOUTH BORDER OF OLD FARGO LANDFILL

FIGURE 7



NORTH-SOUTH CROSS-SECTION ALONG EAST BORDER OF OLD FARGO LANDFILL

FIGURE 8



NORTH-SOUTH CROSS-SECTION ALONG WEST BORDER OF OLD FARGO LANDFILL

FIGURE 9

cipitation; R = surface runoff; AET = actual evapotranspiration over the landfill surface; and S = the gain in the moisture storage within the landfill cover.

The principal source of water for the production of leachate is surface infiltration. Sources of lesser importance include water of decomposition, initial moisture contained in the solid waste, and groundwater infiltration. The amount of infiltration that occurs is governed by surface and climatological conditions at the landfill site. In the water balance analysis, these two conditions are reflected in the parameters: precipitation, surface runoff, evapotranspiration, and soil moisture storage.

Precipitation is strictly a climatic variable and provides the principal source of moisture over the landfill site. Surface runoff is that portion of the incident precipitation that is lost to overland flow before it has a chance to infiltrate. The amount of runoff for any rainfall event is dependent on many factors. These include the intensity and duration of the event, the antecedent soil moisture condition, the permeability and infiltration capacity of the cover soil, the surface slopes, and the amount and type of vegetal cover on the landfill site.

Evapotranspiration represents the amount of available moisture present in the soil that is lost to the atmosphere from the landfill site through direct evaporation from the soil surface and through transpiration by the vegetal cover. As such, it is very much dependent on soil type and vegetation. Evapotranspiration is also closely related to precipitation, temperature, and humidity.

Transpiration alone is responsible for the majority of

moisture lost through evapotranspiration. The amount of moisture lost through transpiration varies with the soil moisture condition. Maximum rate of moisture loss occurs when the landfill soil cover is at or near field capacity, and the rate is reduced as the soil moisture content approaches wilting point. The water balance method takes this effect into account.

The landfill soil cover also affects percolation through its ability to store water. The capacity that a cover soil has for storing water is determined by its type, structure, and depth. The water balance method is concerned with the available water component of the soil moisture storage. This is dependent on soil type, structure, and the effective rooting zone of the vegetal cover. The available moisture varies throughout the year, with evapotranspiration depleting the moisture reserve and infiltration supplying the recharge.

The amount of moisture to which a soil can hold against the pull of gravity is termed the field capacity moisture. Likewise, the minimum amount of moisture to which plants are able to deplete a soil is called the wilting point. Only when a landfill soil cover is at its field capacity moisture content will any infiltrating precipitation percolate to the waste buried below.

Just as the soil cover of a landfill site has a specific field capacity, so does the underlying solid waste. The amount of water that can be added to solid waste before reaching its capacity is dependent on the initial moisture content at the time of placement. This in turn is affected by the composition of the waste and the climate. Previous research indicates that the initial moisture content of municipal solid waste ranges between

10 percent and 20 percent by volume. The field capacity of solid waste has been determined to vary from 20 percent to as high as 35 percent by volume.[8] Until the field capacity of the solid waste has been exceeded, leachate production will be insignificant. Because of the heterogeneous nature of municipal solid waste, some channeling of water may occur causing some leaching to take place prior to the attainment of field capacity. This amount will be small, however, and owing to its interrupted occurrence will be considered negligible for purposes of a water balance.

In short, the water balance method keeps an account of the landfill soil cover moisture. Precipitation adds to the soil moisture, and evapotranspiration withdraws from it. By performing a water balance on the landfill soil cover, the amount of percolation into the solid waste can be determined. The landfill solid waste, with its attendant moisture storage capacity, can then be analyzed in relation to the percolation amounts to determine the time of first appearance of the leachate and the extent of potential leachate problems.

When developing the water balance for the old Fargo landfill, it was necessary to make some initial assumptions. It was felt that in most instances the assumptions were conservatively made with the intent of determining the "worst case" conditions.

Mechanical analysis performed on the old landfill surface soils (0-12 inches) show the soil to be classified as silty clay[5]. The original surface soils of that area were mapped as Fargo-Ryan silty clays[9] and as such were found to exhibit the following moisture holding capacities:

Fargo Series (@ 40% - 60% clay) --

0-8 inches -- 0.15 - 0.18 in/in
8-60 inches -- 0.14 - 0.17 in/in

Ryan Series (@ 40% - 60% clay) --

0-2 inches -- 0.15 - 0.18 in/in
2-60 inches -- 0.10 - 0.14 in/in

Based on a composite of 60 percent Fargo soil and 40 percent Ryan soil, the cover soil at the old landfill would have a maximum moisture holding capacity of 5.16 inches for an assumed effective rooting zone depth of 3 feet. The average depth of cover overlying the waste layer at the old landfill was found to be 8 feet with final surface slopes of less than 2 percent.

In the past, a sizeable area of the old landfill has been seeded to Smooth Brome. For this reason, it was assumed that the eventual use of the site would be an open green area seeded with this particular grass. Information provided by the North Dakota State University Soils Department indicates that Smooth Brome can root in excess of 6 feet. The potential evapotranspiration for Smooth Brome is 24 to 26 inches per year.

The water balance, shown in Table 5, was assumed to start at the beginning of a calendar year. Precipitation data for each month are an average over a 20-year period beginning in January 1961. It was assumed that frozen conditions exist on the average from November 12 to March 31. Precipitation during this period was assumed to change to runoff as spring snowmelt. The monthly distribution of potential evapotranspiration for Smooth Brome was assumed to be proportional to potential evapotranspiration values for this area given by the Thornthwaite and Mather method.[10]

Runoff for the old Fargo landfill site was determined by the

Soil Conservation procedure.[11] Precipitation records for the period January 1961 through December 1980 were obtained from the Fargo, North Dakota, office of the National Weather Service. Daily precipitation amounts over the 20-year period were analyzed for their runoff potential. The results were quantified to provide monthly runoff amounts over an average year (Table 3). The monthly precipitation and runoff values for the old Fargo landfill site are summarized for an average year in Table 4. The results indicate that approximately 8.2 percent of the precipitation occurring during unfrozen conditions results in runoff.

Monthly percolation rates are shown in the last row of Table 5. The only percolation amount appears in April and is less than 1 inch; it was assumed the initial soil moisture condition after spring runoff was 5.16 inches of water or field capacity. This is an extreme assumption in that, on the average, soils in this area do not reach their holding capacity and quite often enter the growing season with a shortage of moisture.[12] It is felt that the amount of percolation shown for April is, therefore, the extreme value, with smaller or no amounts of percolation occurring in a normal year. With surface infiltration contributing at most, a minor amount of water for the production of leachate, it appears that the sources responsible for the water present in the landfill are water of decomposition, initial moisture contained in the solid waste and groundwater infiltration.

Year	Apr	May	June	July	Aug	Sept	Oct	Nov
1961	.03	.08	.00	.19	.08	.35	.01	.00
1962	.00	.46	.16	.58	.39	.06	.00	.00
1963	.39	.18	.03	.00	.62	.00	.00	.00
1964	.34	.00	1.03	.00	.29	.00	.00	.00
1965	.19	.00	.01	.27	.05	.05	.00	.00
1966	.01	.00	.00	.36	.19	---	.01	.00
1967	.08	.00	.05	.00	.00	.00	.00	.00
1968	.10	.00	.03	.01	.00	.00	.01	.00
1969	.22	.11	.06	1.79	.00	.00	.00	.00
1970	.08	.04	.11	.00	.05	1.17	.00	.00
1971	.00	.11	.07	.04	.00	.91	.33	.00
1972	.00	.24	.00	.11	.09	.05	.00	.00
1973	.00	.00	.00	.09	.53	1.06	.05	.00
1974	.13	.14	.00	1.23	1.42	.00	.37	.00
1975	.00	.00	2.36	.08	.19	.05	.03	.00
1976	.00	.00	.00	.00	.00	.00	.00	.00
1977	.00	2.15	.00	1.33	.05	.11	.29	.51
1978	.00	.00	.82	.29	.50	.00	.00	.01
1979	.04	.00	.26	.56	.00	.00	.39	.00
1980	.00	.00	.05	.00	.49	.19	.00	.00
average*	.08	.17	.26	.35	.25	.21	.07	.03

* Average monthly runoff from the years 1961-1980.

TABLE 3. Monthly Runoff, in inches, from Precipitation During Unfrozen Conditions at the Old Fargo Landfill.

MONTH	TOTAL * PRECIPITATION	SNOWFALL * (WATER EQUIVALENT)	RUNOFF FROM * RAINFALL
January	0.67	0.67	0.00
February	0.54	0.54	0.00
March	1.07	1.07	0.00
April	2.21		0.08
May	2.50		0.17
June	3.06		0.26
July	2.94		0.35
August	2.54		0.25
September	2.12		0.21
October	1.49		0.07
November	1.01	0.61	0.03
December	0.73	0.73	0.00

* Based on 20-year averages: 1961-1980.

Precipitation during frozen conditions is assumed to change to surface runoff as spring snowmelt.

TABLE 4. Precipitation and Surface Runoff at the Old Fargo Landfill, in inches of water

	J	F	M	A	M	J	J	A	S	O	N	D	ANNUAL
Ave. Precipitation	.067*	.54*	1.07*	2.21	2.50	3.06	2.94	2.54	2.12	1.49	0.61* 0.40	0.73*	3.62* 17.26
Surface Runoff				0.08	0.17	0.26	0.35	0.25	0.21	0.07	0.03		1.42
Moisture available for infiltration	0.00	0.00	0.00	2.13	2.33	2.80	2.59	2.29	1.91	1.42	0.37	0.00	15.84
Initial Soil Moisture	5.16	5.16	5.16	5.16	5.16	4.26	2.37	0.00	0.00	0.00	0.08	0.45	
Total Available Moisture	5.16	5.16	5.16	7.29	7.49	7.06	4.96	2.29	1.91	1.42	0.45	0.45	
Potential Evapo-transpiration	0.00	0.00	0.00	1.26	3.23	4.69	5.67	4.84	3.03	1.34	0.00	0.00	24.06
Actual Evapo-transpiration	0.00	0.00	0.00	1.26	3.23	4.69	4.96	2.29	1.91	1.34	0.00	0.00	19.68
Remaining avail-able moisture	5.16	5.16	5.16	6.03	4.26	2.37	0.00	0.00	0.00	0.08	0.45	0.45	
PERCOLATION	0.00	0.00	0.00	0.87	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87

* Precipitation during frozen conditions (Nov. 12 to March 31) is assumed to change to runoff as spring snowmelt.

NOTE: All table values are in inches of water.

TABLE 5. Water Balance Analysis for the Old Fargo Landfill

HYDROGEOLOGIC CONDITIONS

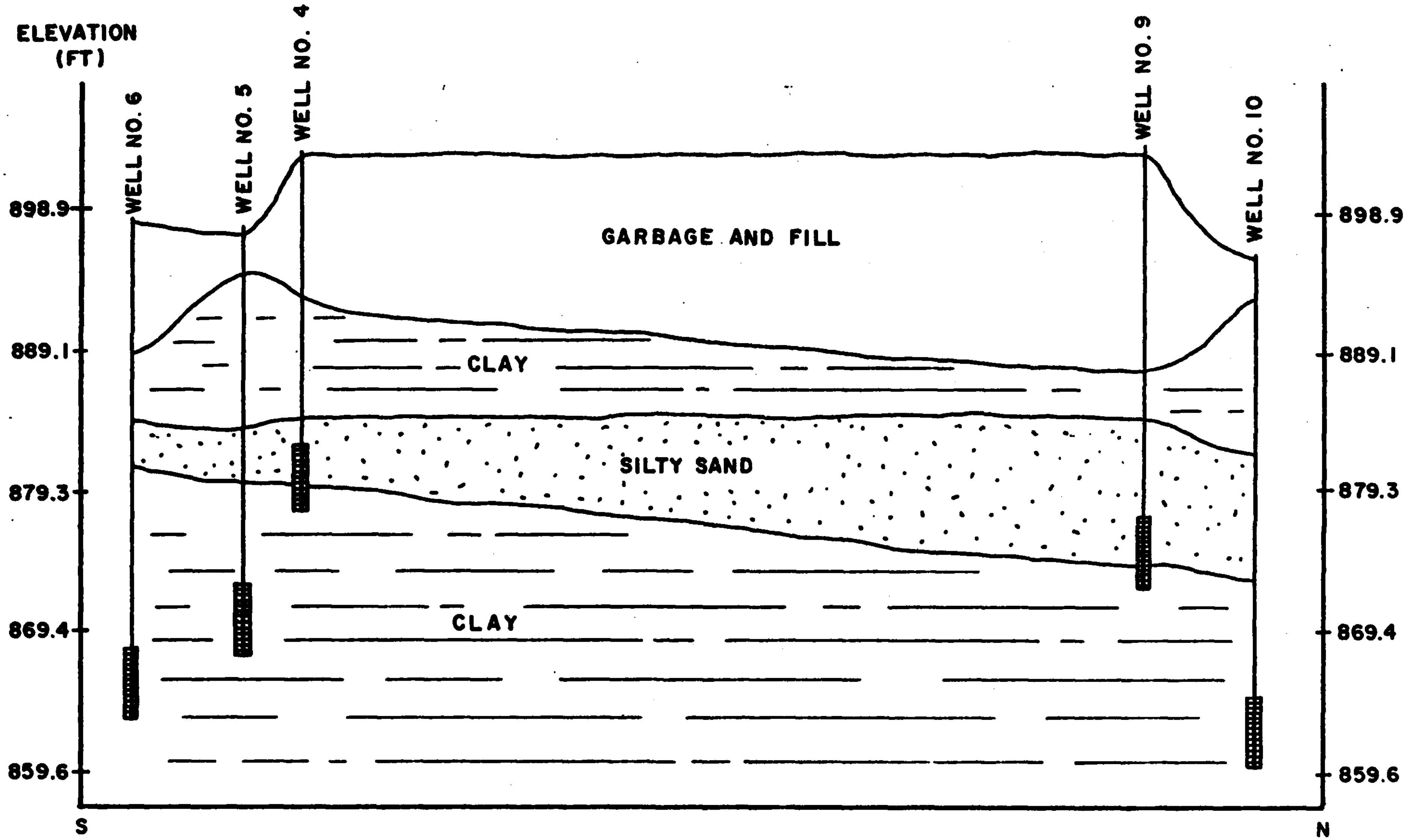
Groundwater Movement

Eleven wells were installed on or adjacent to the old Fargo landfill (Figure 1). Four additional wells designated as L1, L2, L3, and L4 were installed during an earlier study[5] and were included for monitoring purposes. All observation wells functioned equally as piezometers for water level measurements. The 11 new wells were located around the perimeter of the landfill and were placed below the zone of saturation (Figures 10 and 11). The older wells are located in the landfill site and were completed in refuse. The drilling logs for the 11 newer wells are indicated in Appendix III.

During the period of highest water table levels, depth from the ground surface to the water table ranged from 5-1/2 feet in the southwest corner of the landfill to 11-1/2 feet just outside the north boundary of the landfill. The shallow water table within the landfill may well indicate the occurrence of groundwater mounding.

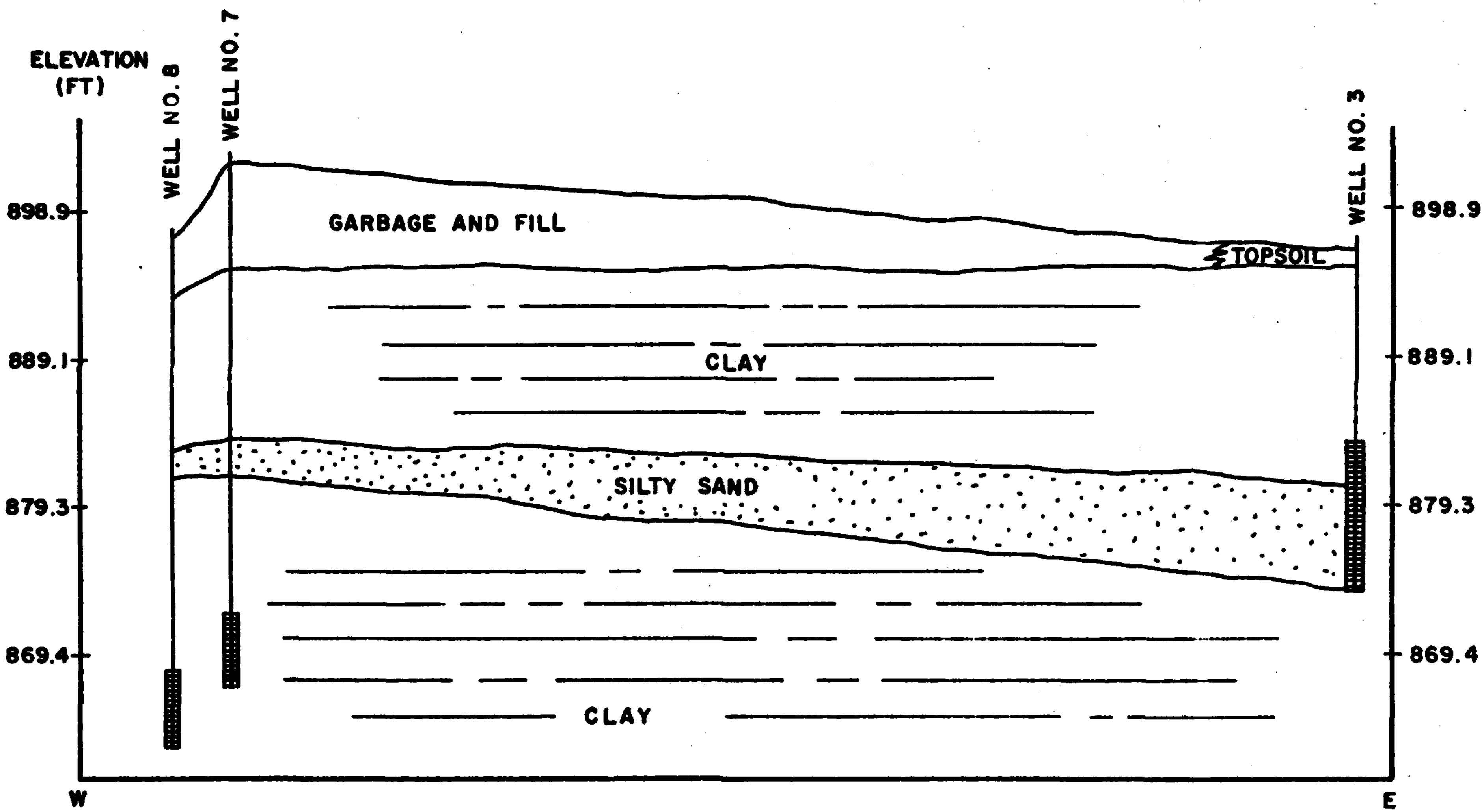
The water table varied seasonally, the highest levels occurring during the spring and early summer (Graphs 1, 2, and 3). A decrease in water table elevation occurred from June 1983 through August 1983, a condition that may have been caused by an insufficient recovery of water levels following groundwater sampling. This condition was particularly evident in wells 1, 7, and 5 (Graph 3). The water table elevation in well 11 was below 853 feet during the entire monitoring period.

Daily precipitation records were obtained from the National Weather Service in Fargo, North Dakota, for the period September



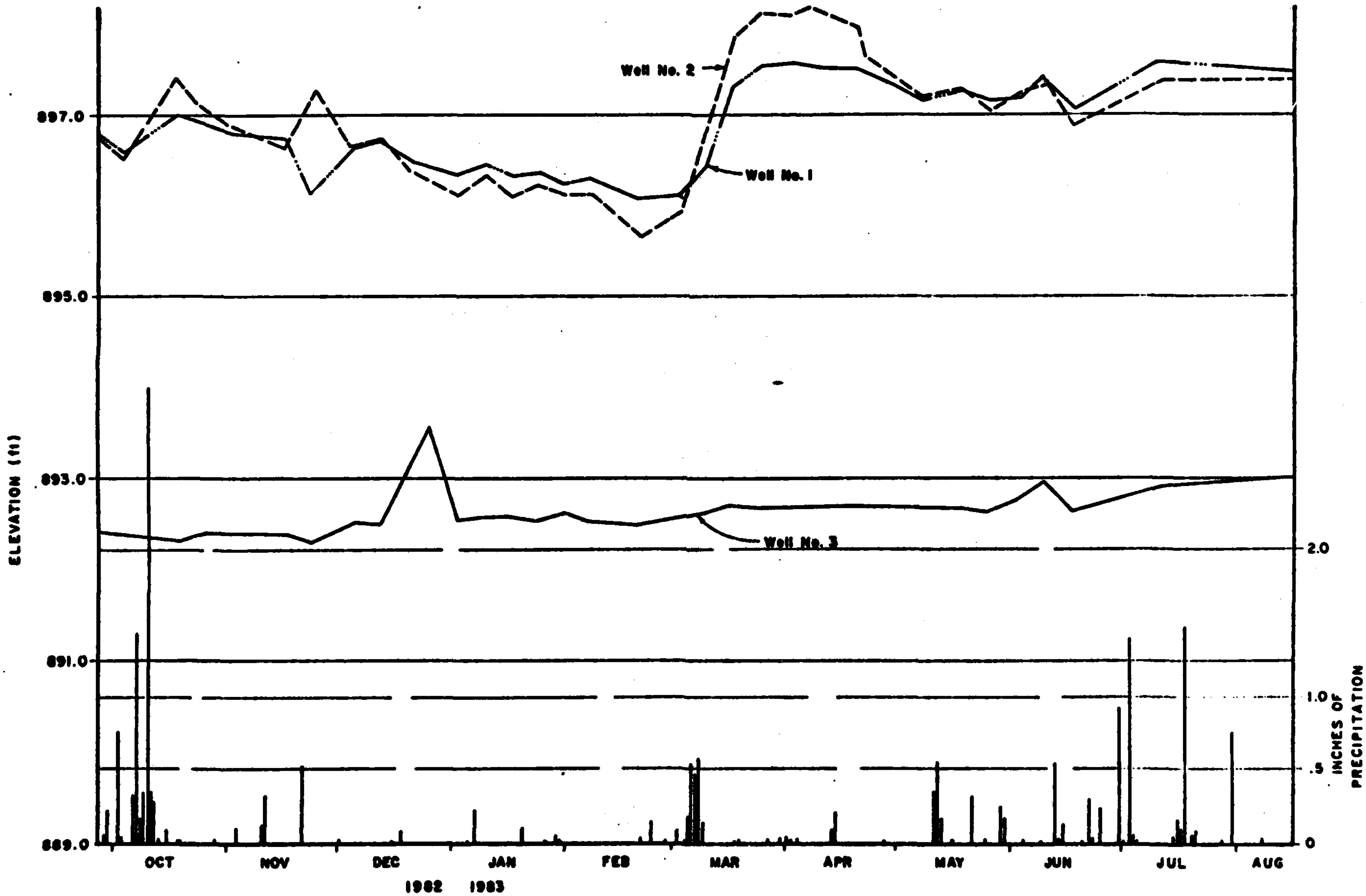
NORTH-SOUTH CROSS-SECTION THROUGH MIDDLE OF OLD FARGO LANDFILL

FIGURE 10

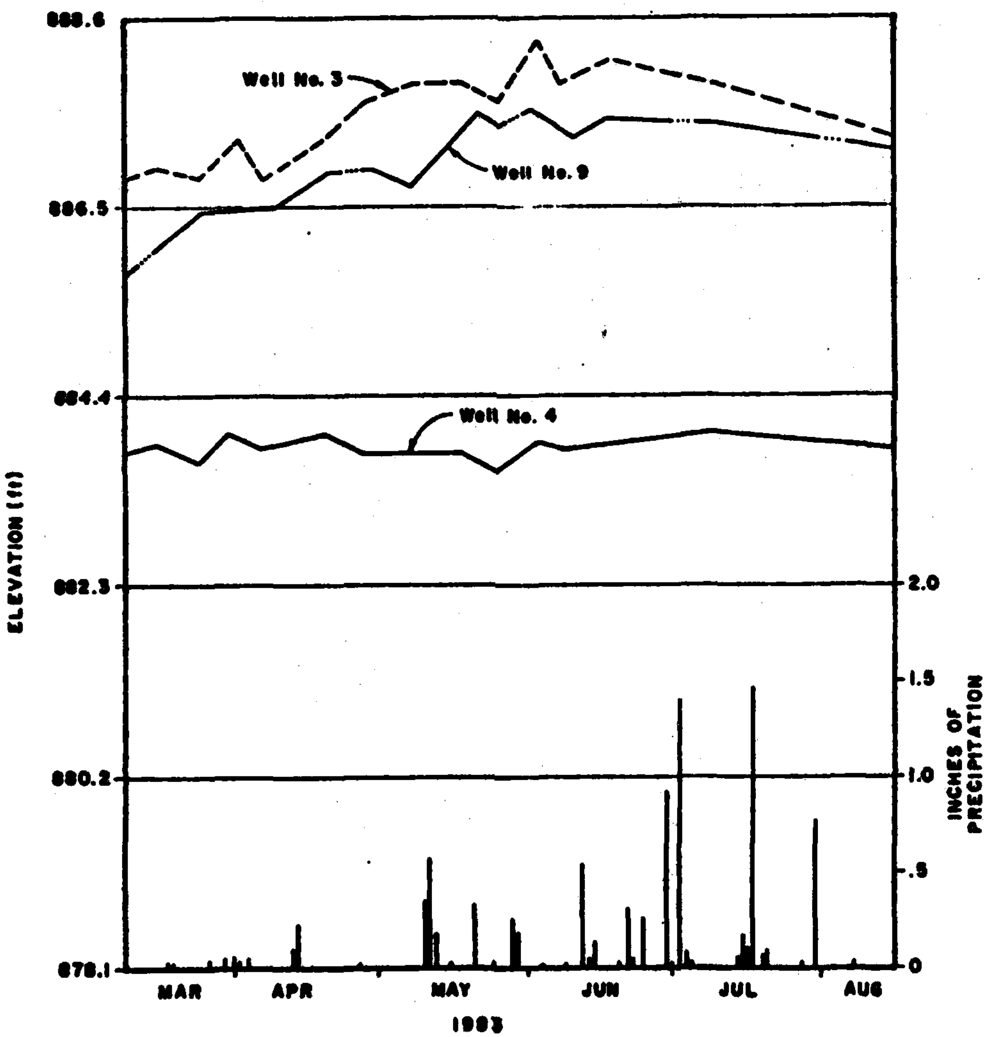


EAST-WEST CROSS-SECTION THROUGH MIDDLE OF OLD FARGO LANDFILL

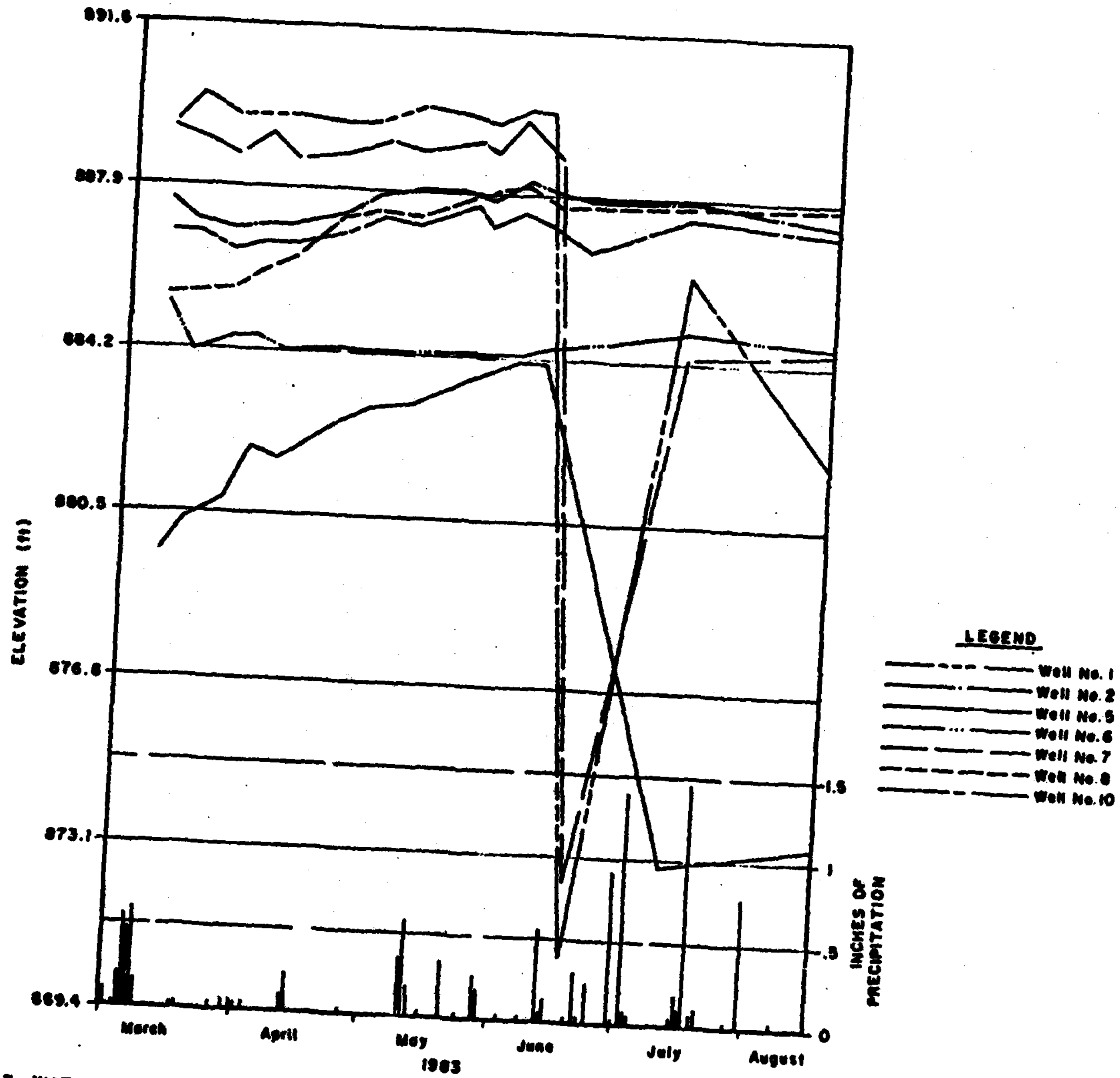
FIGURE 11



GRAPH 1 - WATER LEVEL ELEVATIONS AND PRECIPITATION TOTALS AT WELL SITES L1, L2, AND L3



GRAPH 2- WATER LEVEL ELEVATIONS AND PRECIPITATION TOTALS AT WELL SITES 3, 4, AND 9

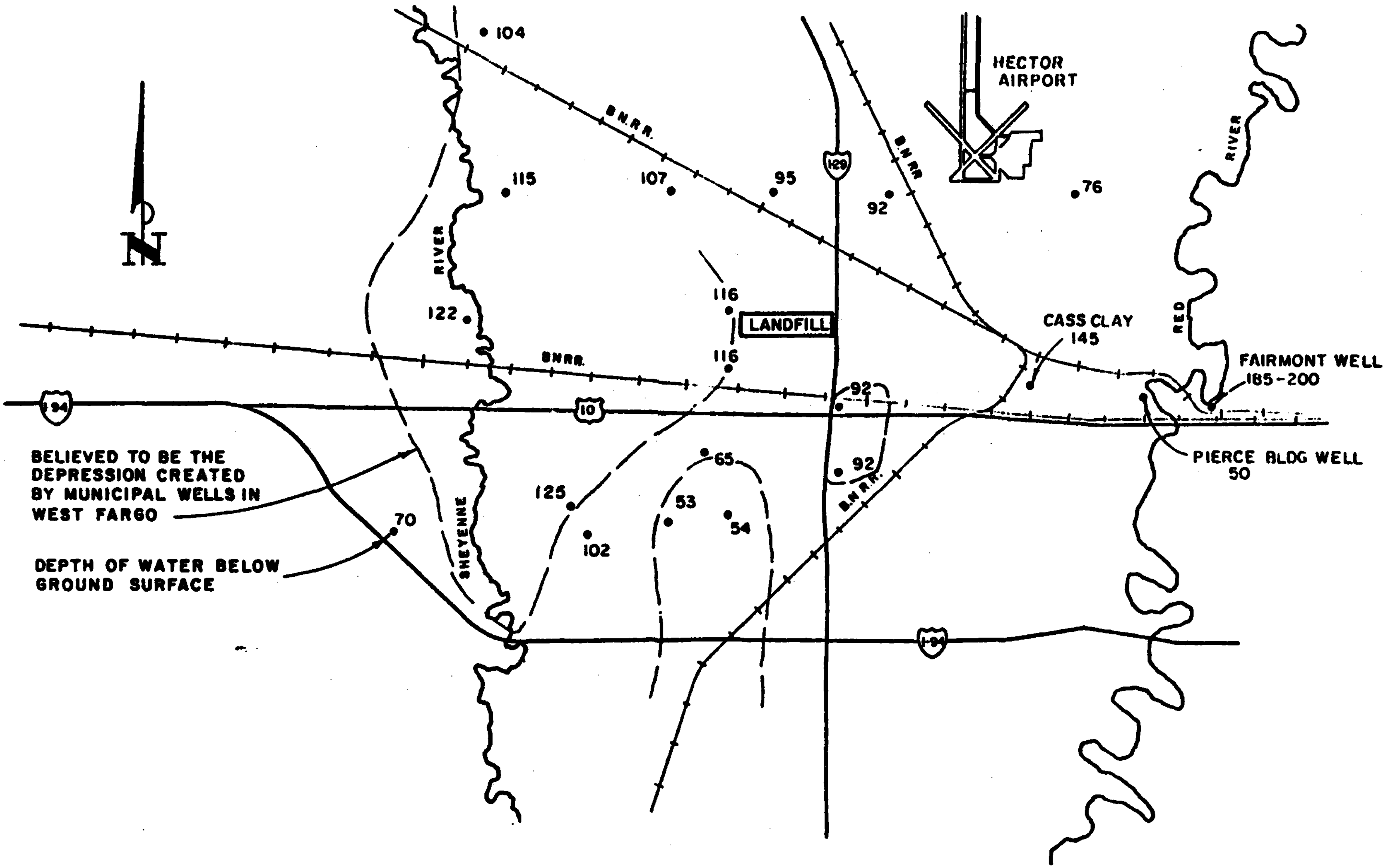


GRAPH 3 - WATER LEVEL ELEVATIONS AND PRECIPITATION TOTALS AT WELL SITES 1,2,5,6,7,8, AND 10

1982 through September 1983. Rain gage data are recorded at Hector International Airport, approximately 5 miles from the landfill site. Wells L1 and L2 appear to respond to major precipitation events with a corresponding increase in water level elevation (Graph 1). A similar response is not evident in the other wells.

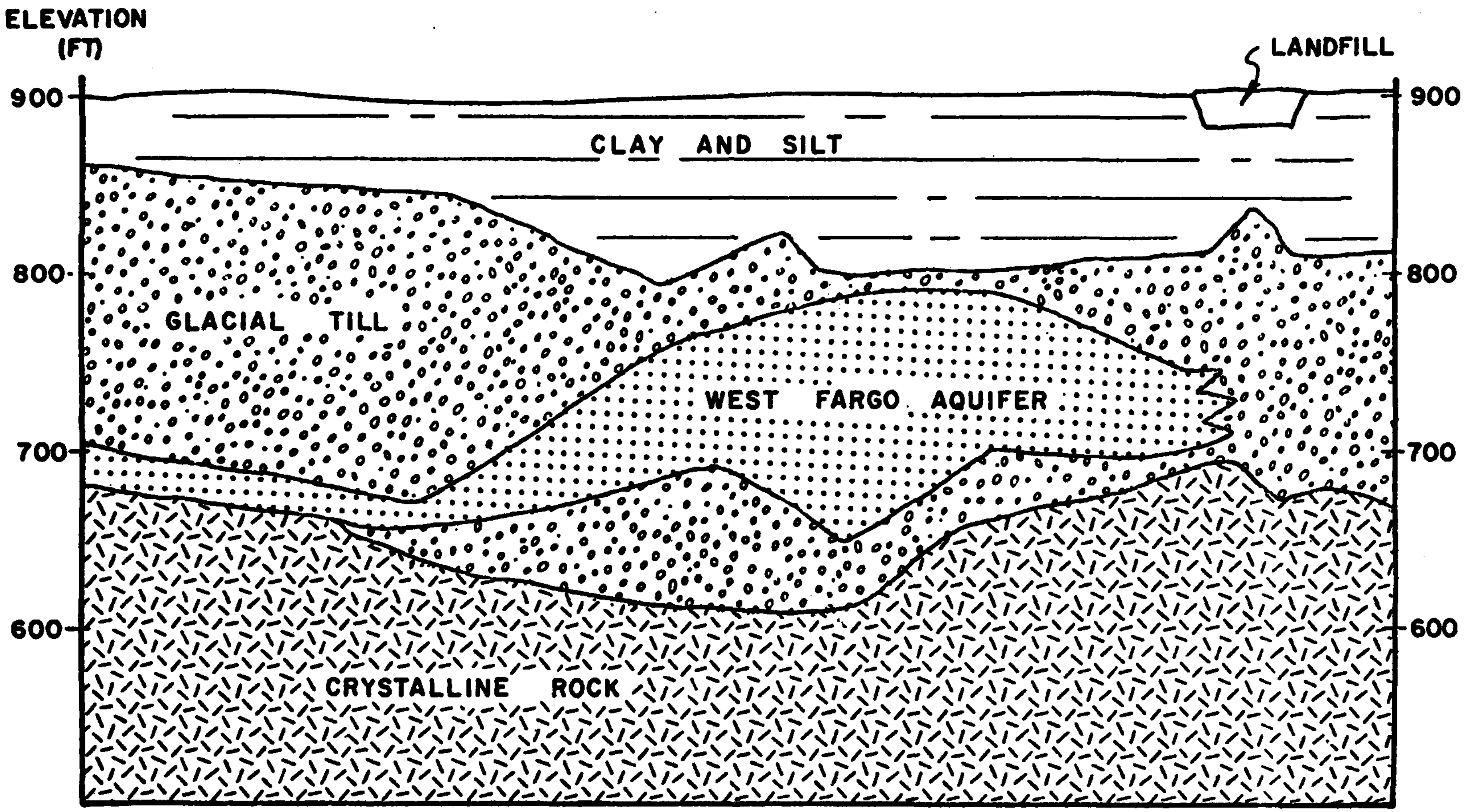
Movement of groundwater is from areas where the elevation of the water table is high to areas where the water table elevation is low. Not accounting for wells L1, L2, and L3 and the possibility of groundwater mounding, the general groundwater flow direction appears to be from north to south. Wells 4, 5, and 6 intersect the south boundary of the landfill and show the lowest piezometric surfaces (Graphs 2 and 3).

The most recent information on pumping tests conducted by the North Dakota State Water Commission in the vicinity of the old Fargo landfill shows the landfill as being located on the east edge of a cone of depression for a municipal well supplying the city of West Fargo, North Dakota (Figure 12). The general flow direction within the area of drawdown adjacent to the old Fargo landfill is to the southwest. Municipal water for West Fargo is supplied by the West Fargo Aquifer. Depth from the ground surface to the aquifer ranges from 80 to about 170 feet.[2] The distance separating the bottom of the refuse cell in the landfill and the West Fargo Aquifer is roughly 125 feet (Figure 13). The interlying material consists chiefly of lake bottom clays and till. The influence that the cone of depression within the West Fargo Aquifer has on the shallow groundwater system in the area of the old Fargo landfill is not known.



DEPTH OF WATER BELOW GROUND SURFACE IN THE VICINITY OF THE FARGO LANDFILL — FALL OF 1982

FIGURE 12



GEOLOGIC CROSS-SECTION OF WEST FARGO AQUIFER IN THE VICINITY OF THE OLD FARGO LANDFILL.

FIGURE 13

Groundwater Chemistry

Chemical analyses of samples taken from each of the observation wells were used to determine the extent of groundwater pollution in the immediate area of the old Fargo landfill. Concentrations of most of the major and minor dissolved inorganic constituents in the groundwater were determined to characterize groundwater quality in the vicinity of each of the wells. In addition, concentrations of several trace constituents were determined because of their known toxicity. Specifically, arsenic, barium, cadmium, chromium, lead, on a selenium are known toxicants. Selenium is, also, quite possibly a carcinogen.[16] The presence of nitrate in concentrations in excess of 10 mg/l nitrate nitrogen in drinking water can cause methemoglobinemia in infants. Upon ingestion, the nitrate ion is acted upon by bacteria and converted to nitrite. Nitrite then converts hemoglobin to methemoglobin. Hemoglobin is the oxygen carrier in the bloodstream. The altered hemoglobin molecule can no longer transport oxygen with the resulting physiological effect being oxygen deprivation. Organic analyses included 4 chlorinated hydrocarbon insecticides (endrin, lindane, toxaphene, and methoxychlor) and 2 chlorophenoxy herbicides (2, 4-D and 2, 4, 5-TP silvex). All 6 compounds are widely used and considered toxic.[16]

Unfiltered groundwater samples, with the exclusion of those designated for dissolved orthophosphate, dissolved phosphate, and nitrate analysis, were intentionally used for mineral and trace metal analyses to determine maximum potential concentrations and their resultant pollution potential. The results of the chemical

investigations performed by the North Dakota State Public Health Laboratory and the North Dakota State University Sanitary Laboratory are presented in Tables 6 and 7.

Generally, chemical analyses of groundwater can be used to interpret groundwater movement. As groundwater moves through and away from a point source of contamination, changes in water quality can be monitored. Because of surrounding land use restrictions, observation well locations for this study were limited to the periphery of the old Fargo landfill precluding the use of the results of the chemical analyses for determining groundwater movement.

Nearly all of the major and minor dissolved constituents of groundwater are in an ionic form. As a consequence, a general indication of the total dissolved ionic constituents can be determined by measuring the electrical conductance of the water. It is the charged ionic species present in solution that conduct a current but, because of the presence of various uncharged species in addition to the charged ions, conductance determinations cannot be used to obtain accurate estimates of total dissolved solids. Electrical conductivity values in general, however, give an indication of total dissolved solids.[17]

Analyses of both a filtered and unfiltered groundwater sample from well 1 are presented in Table 6. The conductivity and total dissolved solids concentration for the unfiltered sample showed an increase over the filtered samples of 150 percent and 400 percent, respectively. There appears to be no consistent relationship of conductivity to TDS between the two samples. The unfiltered analyses, however, are thought to be a reliable

Well No.	Conductivity (umhos/cm)	TDS (mg/l)	pH	COD (mg/l)	Total Hardness (mg/l as $CaCO_3$)	Total Alkalinity (mg/l as $CaCO_3$)
1 (unfiltered)	2013/922.86*	4070	7.6	761	4000	2480
1 (filtered)	1314	1050	7.5	--	861	439
2	2926/1607.92	3530	7.6	216	1970	1230
3	5355/4901.67	7820	12.0	200	4820	5060
4	7807/5216.67	9480	8.0	244	4560	1870
5	3441/2500	3930	7.8	530	2170	857
6	4417/3147.27	4430	7.7	55	1910	560
7	10120/2735.26	3770	7.8	369	2070	901
8	2990/2156.25	2910	7.9	97	1490	602
9	7751/5792.31	7210	7.8	97	3100	1110
10	4482/3032.26	4420	7.8	145	1810	494
11	824/182.25	576	8.2	33	272	332
Pond						
L1	5124/3320.83	3050	7.5	492	1140	1810
L2	11240/8242.86	7530	7.7	1000	1090	3300
L3	10130/8444.44	7030	7.8	1030	1890	5930

* Average of conductivity measurements taken in the field.

TABLE 6. Results of Chemical Analysis Performed by State Public Health Laboratory

Well No.	Ca (mg/l)	Mg (mg/l)	Mn (mg/l)	Na (mg/l)	K (mg/l)	Fe (mg/l)	Total Phosphate (mg/l as P)	Ortho Phosphate (mg/l as P)	CO_3 (mg/l as CO_3)
1 (unfiltered)	1040	338	21	192	20	510	.069	.024	0
1 (filtered)	242	62.5	1.10	173	8.85	.03	--	--	0
2	568	135	7.32	323	13.1	39.4	.037	.017	0
3	1490	205	13.6	708	198	156	.091	.001	2950
4	908	558	27.8	1410	17.4	174	.085	.056	0
5	580	175	9.85	439	15.0	91	.081	.062	0
6	510	155	4.36	560	10.6	0.73	.017	.009	0
7	548	170	9.30	412	14.9	56.5	.074	.052	0
8	412	112	2.47	250	10.5	6.7	.027	.024	0
9	605	385	6.46	1120	18.4	15.0	.034	.021	0
10	490	142	4.12	464	9.0	7.28	.038	.013	0
11	79	18	.246	83	7.15	.92	.036	.013	0
Pond									
L1	135	195	.835	608	83.8	18.6	.131	.085	0
L2	74	221	.232	1690	284	26.2	.416	.392	0
L3	69.5	418	.132	1580	301	15.5	1.18	1.00	0

TABLE 6. Continued

Well No.	HCO_3 (mg/l as HCO_3)	CL (mg/l)	F (mg/l)	SO_4 (mg/l as SO_4)	NO_3 (mg/l as N)	NH_3 (mg/l as N)	TKN (mg/l)	SAR
1 (unfiltered)	3030	105	0.1	877	.017	.974	16.1	1.32
1 (filtered)	536	--	---	--	--	--	--	2.56
2	1500	80	0.2	1670	.045	.419	3.9	3.17
3	177	205	0.0	1910	.045	1.64	8.14	4.44
4	2290	345	0.1	5120	.009	.179	6.83	9.09
5	1050	200	0.1	2000	.008	.716	4.64	4.10
6	684	260	0.1	2600	.008	.882	.884	5.56
7	1100	400	0.1	1690	.008	.714	4.42	3.94
8	735	265	0.1	1500	.097	.569	1.74	2.81
9	1350	850	0.2	3410	33.0	.760	1.55	8.77
10	603	300	0.1	2720	.029	.539	.758	4.74
11	405	80	0.6	109	.020	.580	.226	2.19
Pond					.009	103	3.06	
L1	2200	850	0.1	89	106	3.06	7.84	7.84
L2	4030	3250	0.1	21	.010	470	299	22.2
L3	7240	1050	0.1	39	.029	327	156	15.8

TABLE 6. Continued

Well No.	As (ug/l)	Be (ug/l)	Cd (ug/l)	Cr (ug/l)	Cu (ug/l)	Pb (ug/l)	Se (ug/l)	Ag (ug/l)	Zn (ug/l)
1	142	130	31.6	580	875	300	5.10	.12	1940
2	12.6	90	4.26	17.4	40	19.5	0.25	0.13	82
3	24.7	130	1.08	52.0	46	28.8	0.89	0.17	98
4	30.4	10	2.92	43.8	32	30.7	0.00	0.06	370
5	12.9	70	1.38	17.4	23	14.0	0.17	0.22	58
6	14.2	40	0.88	4.61	20	7.2	0.08	0.11	40
7	25.1	150	1.52	29.4	56	18.2	0.68	0.00	89
8	18.1	130	1.25	8.60	28	11.2	0.00	0.00	68
9	33.5	90	3.23	34.7	65	52.4	0.21	0.20	1470
10	16.8	60	0.74	3.48	12	2.9	0.00	0.00	43
11	14.8	40	.74	4.94	7	4.6	.06	0.00	24
Pond	24.3	170	0.00	11.5	1	2.5	0.00	0.00	27
L1	18.7	360	.80	8.43	26	64.6	0.00	0.07	152
L2	21.3	1220	1.09	17.8	17	68.5	0.00	0.00	148
L3	16.3	820	2.38	23.4	16	45.8	0.03	0.00	326

TABLE 6. Continued

Well No.	pH	Total Alkalinity (mg/l as $CaCO_3$)	Total Hardness (mg/l as $CaCO_3$)	Calcium Hardness (mg/l as $CaCO_3$)	COD Filtered/Unfiltered (mg/l)	BOD_5 (mg/l)
1	7.3	345.15	800	540	120/213	30.0
2	7.3	263.25	890	510	96/127	24.1
3	11.55	688.3	460	430	96/347	--
4	6.95	878.3	3150	1210	20.75/210.47	250.7
5	7.3	471.9	1540	950	54.35/80.04	5.0
6	6.85	510.9	2040	1330	18.77/14.82	6.6
7	6.9	475.8	1780	1050	183/1448	31.6
8	7.0	510.9	1780	1060	116/209	26.6
9	7.1	895.1	3260	1400	89/147	8.3
10	7.0	468.0	2240	1440	127/146	21.6
11	7.5	390.0	420	260	26.3/26.3	9.1
Pond	8.3	2397.5				
L1	7.4	1721.9	1340	360	265/319	30.7
L2	7.2	3006.9	1220	250	776/786	48.3
L3	7.6	5359.9	2220	180	842/914	40.0

TABLE 7. Results of Chemical Analyses Performed by NDSU Sanitary Laboratory

indication of major ion concentrations and, in general, a measure of the level of groundwater contamination.

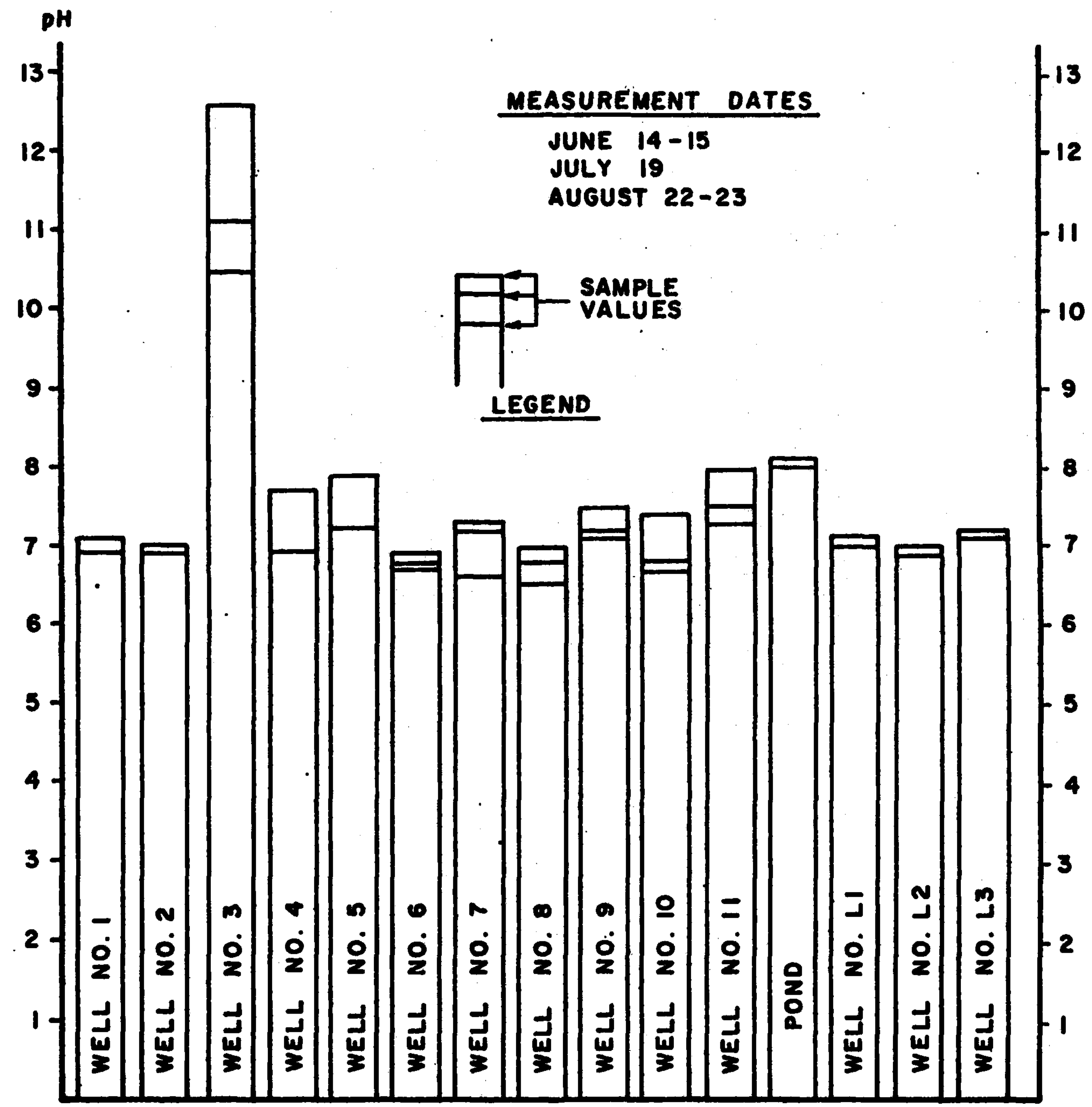
Piezometers L1, L2, L3, and L4 are located inside the landfill site and are screened at the bottom of a waste cell. Piezometers L1, L2, and L3 indicate that the groundwater in the refuse cells is severely contaminated, piezometer L1 to a lesser degree than the other two. This difference could possibly reflect a variation in waste composition in the vicinity of piezometer L1. Peizometer L4 did not intercept the groundwater surface and, consequently, no samples were collected.

Piezometers 3, 4, and 9, in general, show a higher degree of contamination than the other peripheral well sites. Specifically, the three piezometers show significant concentrations of chloride, sulfate, and sodium. The three sites also indicate high specific conductances and high concentrations of total dissolved solids. Chloride is commonly used as an indicator for groundwater contamination. Solid waste products generally contain materials that yield relatively large amounts of chloride and it is considered a conservative species in that it is least affected by absorption, exchange, and biochemical conversion reactions.[13,14] It is interesting to note that piezometers 3, 4, and 9 are the only observation wells to be screened at the level of the silty sand layer. In addition, piezometers 4 and 9 were the only borings that penetrated a garbage layer. The screens, however, were placed approximately 16 feet below this layer and are separated from the waste cell by a clay layer varying in thickness from 3 to 8-1/2 feet. It is felt that the trend exhibited in these three wells could possibly indicate that the

silty sand layer acts as an independent, shallow, groundwater flow system.

pH was measured in the field at the time of sampling. Results of the measurements for the three separate sampling occasions are presented in Graph 4. In general, pH values ranged from 6.5 to 8.0. Most notable and of some concern are the pH values obtained in observation well 3. The measured values obtained on the three separate sampling occasions ranged from 10.44 to 12.63. The North Dakota State Department of Health, Division of Environmental Waste Management and Research has, under general authority of NDCC 23-20.3-03, classified any aqueous material with a pH greater than 12.5 as a hazardous waste due to its corrosivity[18]. Boring 3 was drilled to a depth of 23 feet and screened at the silty sand layer. Piezometers 1, 2, and 3 constitute a three-level piezometer nest, piezometer 3 being the shallow piezometer. Water table elevations (Graphs 2 and 3) indicate minor vertical groundwater movement between piezometers 3 and 2 - the next deepest piezometer at a depth of 30 feet. An open pond exists on the landfill site approximately 50 feet to the west of piezometer 3. In the past, this pond has been used by a local industry for the disposal of "paint sludge." Measurement of pH in this pond throughout the summer (1983), however, produced values ranging from 8.02 to 8.30. At present, there appears to be no obvious reason for the high pH in piezometer 3.

Table 8 presents the current Safe Drinking Water Standards for the State of North Dakota.[15] Several of the observation



pH MEASUREMENTS AT OBSERVATION WELL SITES

GRAPH 4

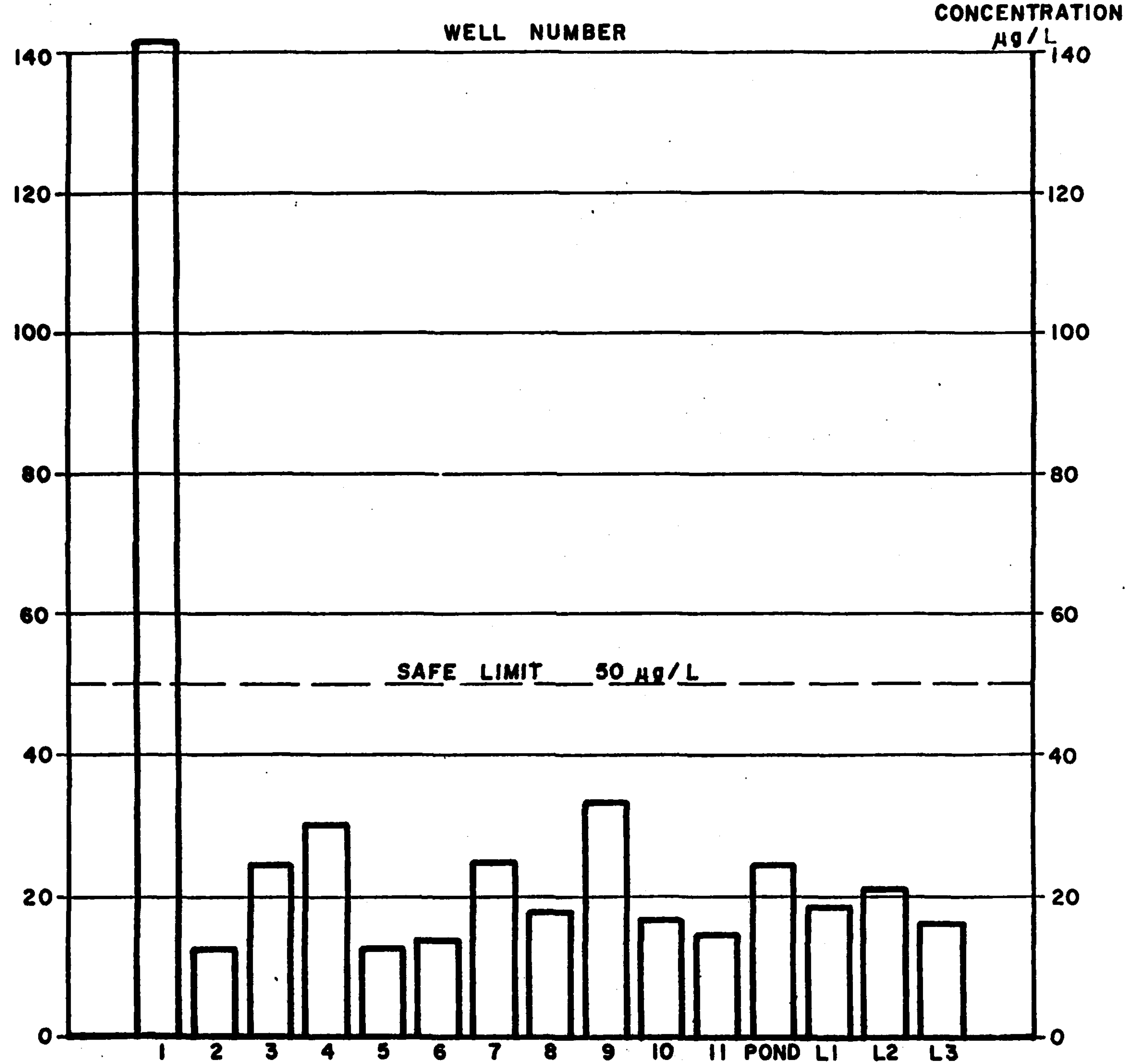
Contaminant	Level Milligram Per Liter
Arsenic	0.05
Barium	1
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10
Selenium	0.01
Silver	0.05
Fluoride	2.4

TABLE 8. North Dakota Safe Drinking Water Standards.

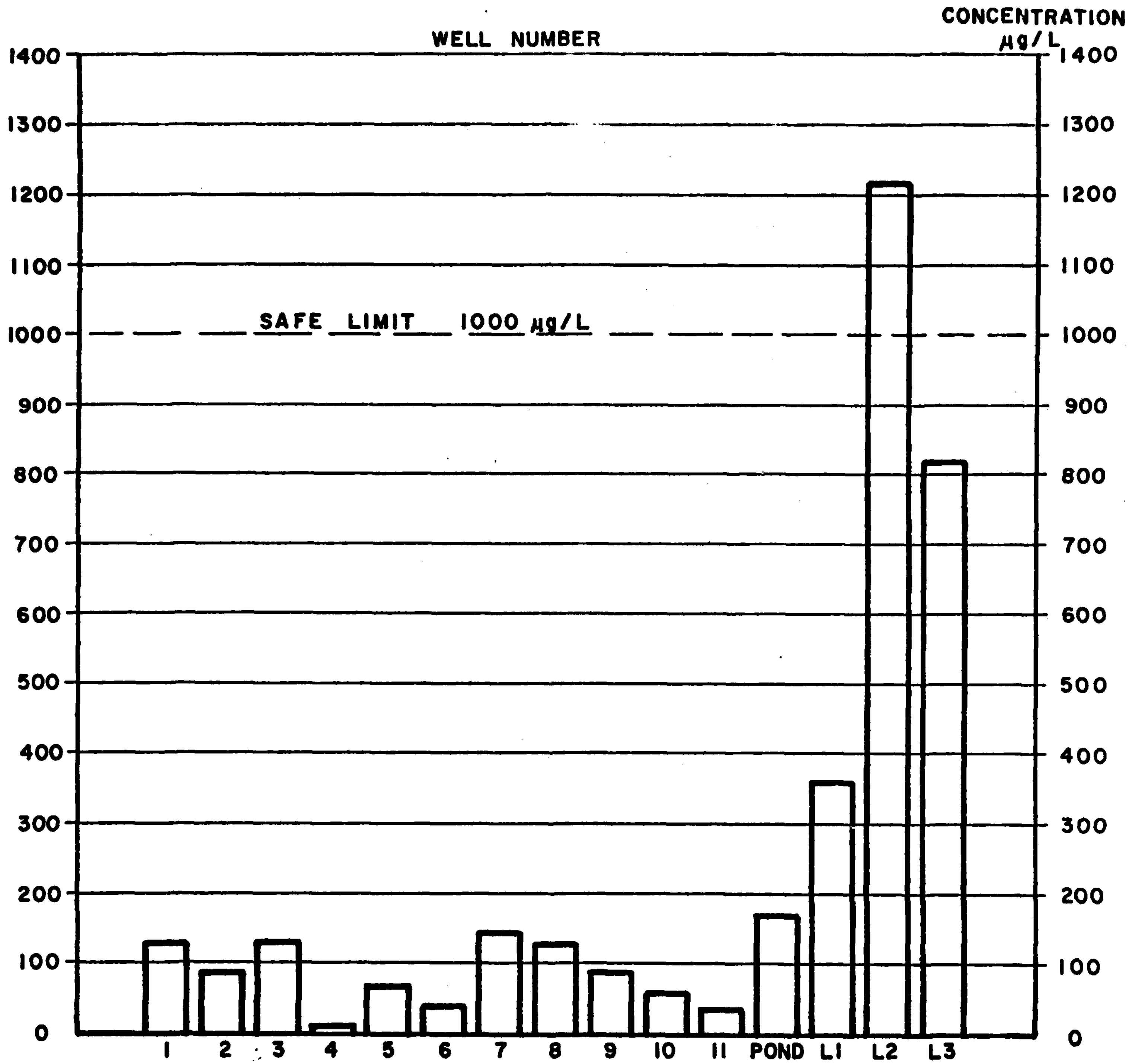
sites exhibited excesses of the standards in a number of categories, specifically, trace metal concentrations (Graphs 5, 6, 7, 8, and 9).

Analysis of groundwater withdrawn from well 1 indicates concentrations of arsenic, cadmium, chromium, and lead in excess of the Safe Drinking Water Standards. Very probably the high concentrations of metals in well 1 were due in part to the fact that the samples were not filtered. Well 1 is the deepest well of the three-level piezometer nest located on the east boundary of the old landfill. It is a 50-foot well that is screened in a layer of clay extending 27 feet below the silty sand layer underlying the landfill. The high piezometric surface of well 1 in relation to the piezometric surfaces in wells 2 and 3 indicates a vertical upward movement of groundwater in this area (Graphs 2 and 3).

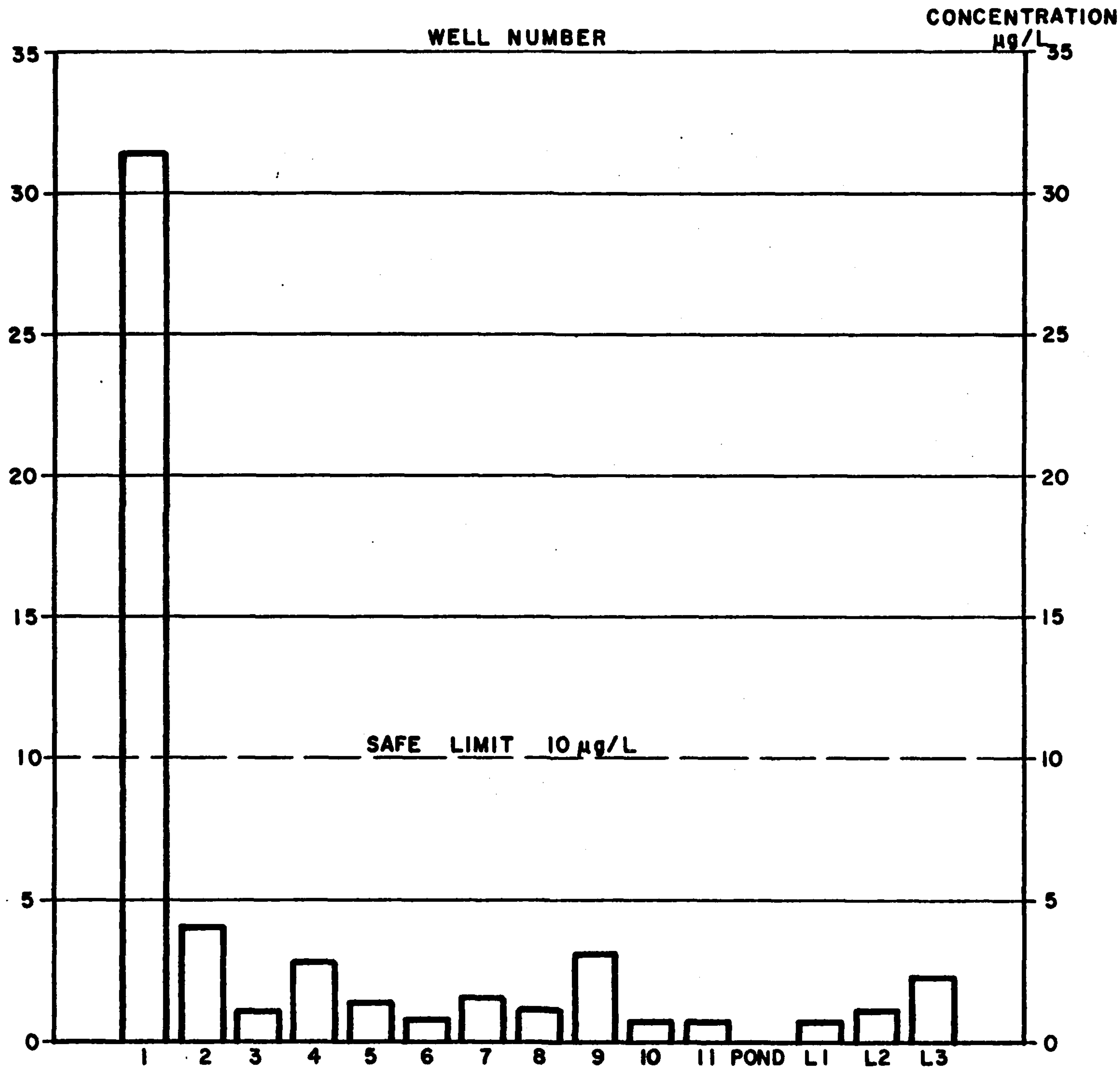
The North Dakota State Public Health Laboratory performed pesticide and herbicide analyses on groundwater samples collected during August 1983. In addition, pesticide analysis was performed on samples collected in July 1983. The laboratory results on both occasions showed no detectable amounts of any of the two classes of compounds. Results of the chemical analyses performed by the North Dakota State Public Health Laboratory are given in Appendix II.



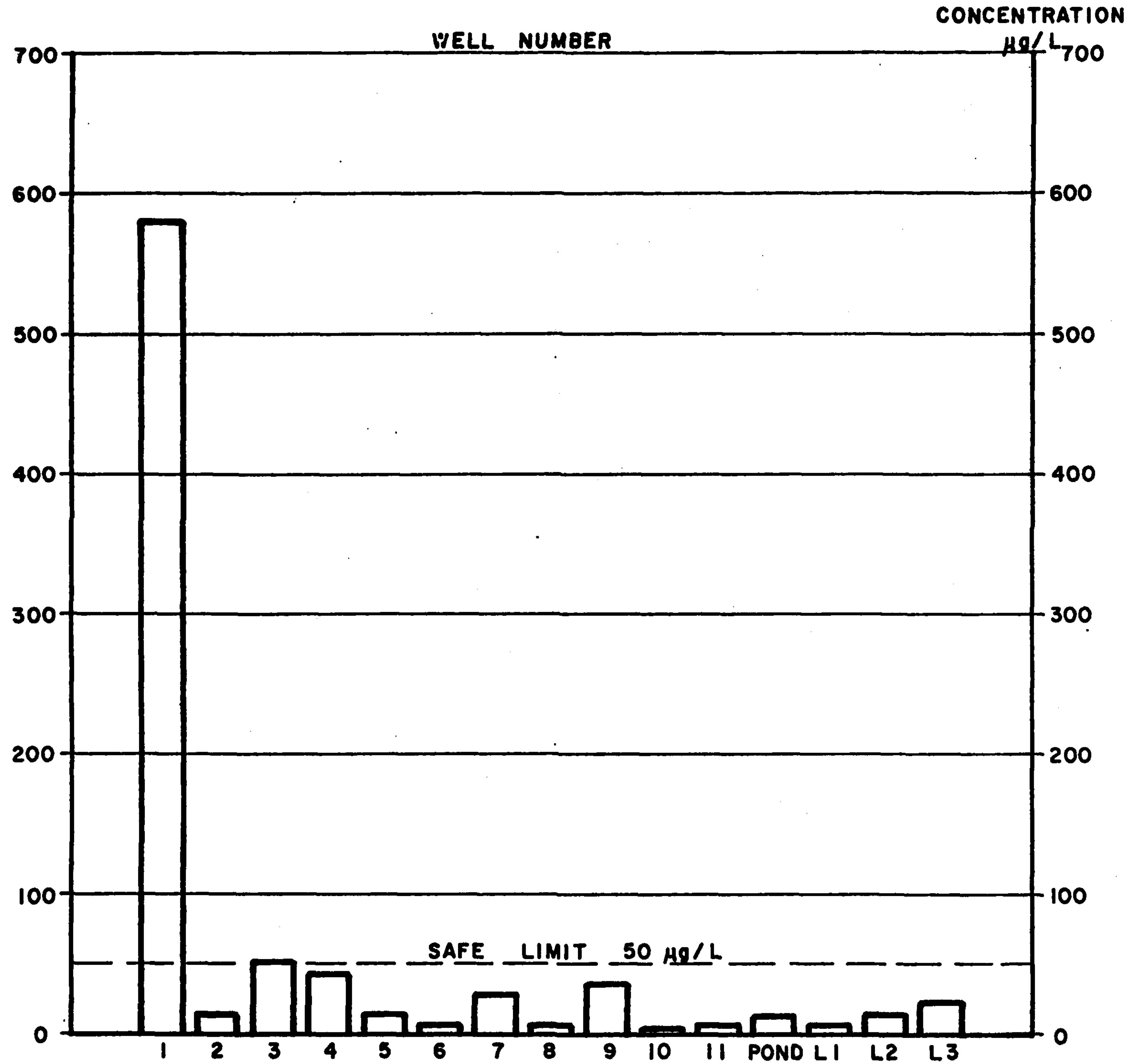
GRAPH 5 - ARSENIC CONCENTRATIONS AT OLD FARGO LANDFILL



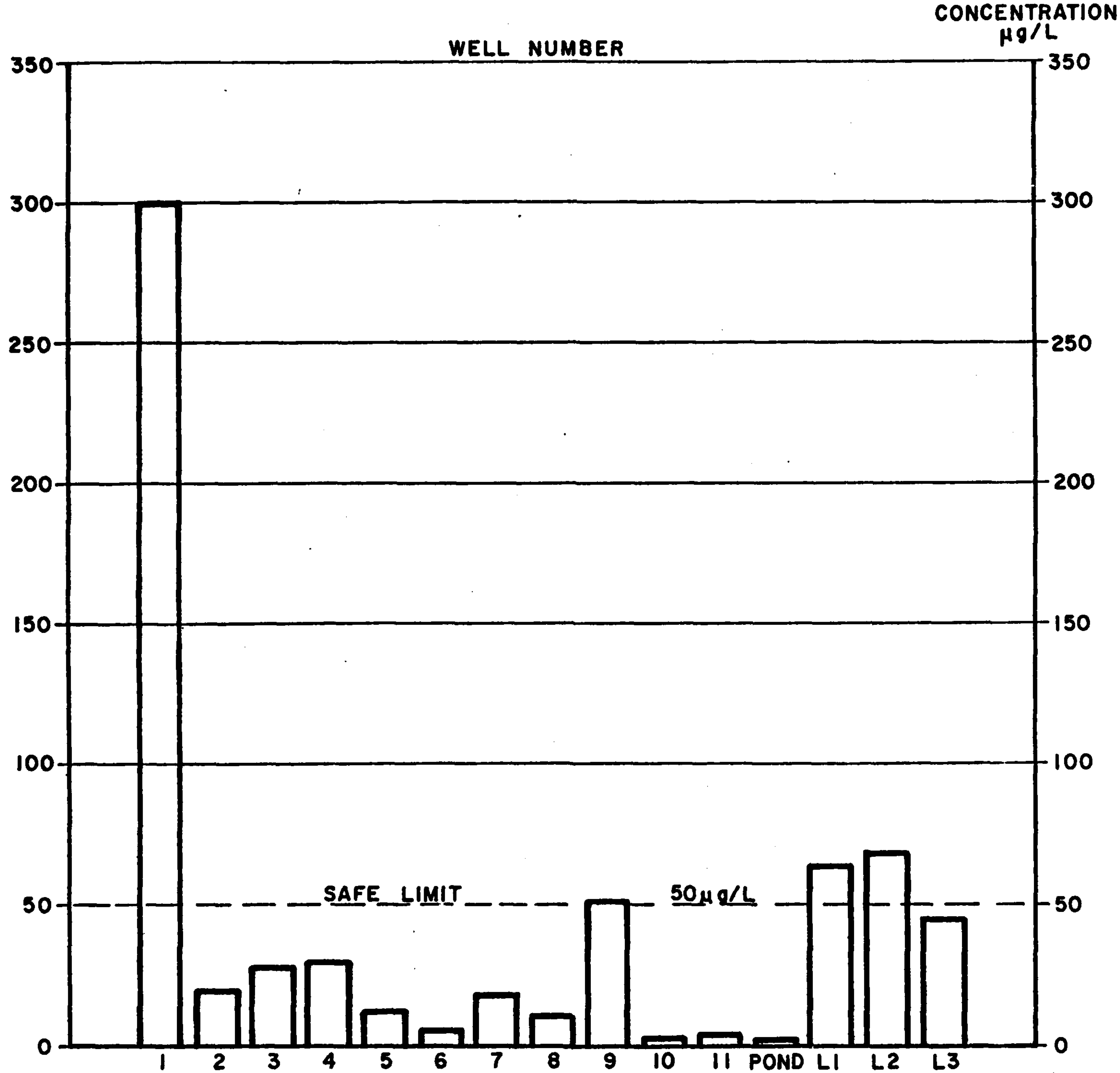
GRAPH 6 - BARIUM CONCENTRATIONS AT OLD FARGO LANDFILL



GRAPH 7 — CADMIUM CONCENTRATIONS AT OLD FARGO LANDFILL



GRAPH 8-CHROMIUM CONCENTRATIONS AT OLD FARGO LANDFILL



GRAPH 9 – LEAD CONCENTRATIONS AT OLD FARGO LANDFILL

CONCLUSIONS

The old Fargo landfill, in general, consists of one 8-foot lift of garbage. The refuse layer is overlain by cover soil ranging in depth from 6 to 10 feet. Well log and test boring records show a silty sand layer 13 to 18-1/2 feet below the landfill surface. Past operational history indicates that the landfill trenches did not intercept this silty sand layer at the time of waste placement. The landfill site is immediately underlain by a brown and gray mottled clay. This clay layer separates the refuse from the silty sand layer. At all well locations, the sitly sand layer is underlain by clay. Cross sections of the site indicate that the silty sand layer increases in thickness in the south and east directions. Depth from the surface to the silty sand layer increases slightly in the direction of the northeast corner of the landfill site.

Chemical analyses on groundwater samples indicate some degree of groundwater contamination in all wells except well 11 which was screened in clay at a depth of 100 feet. Wells L1, L2, and L3 are completed in refuse and show severe contamination with dissolved solids. Wells 3, 4, and 9 all of which were screened at the silty sand layer, show evidence of severe contamination. Chloride, sodium, and sulfate ion concentrations were particularly high. Chloride is commonly used as an indicator for groundwater contamination. Its presence here is attributed to the landfill solid waste.

Several wells show concentrations of selected trace metals in excess of safe drinking water standards. Most notable is well 1

with concentrations of arsenic, cadmium, chromium, and lead in excess of safe limits. Groundwater samples from well 3 show consistently high pH values. pH varied from 10.4 to 12.6. The North Dakota State Department of Health classifies any aqueous material with a pH greater than 12.5 as being a hazardous waste. There was no obvious reason for this extreme.

During periods when the water table was highest, depth to the water surface was only 5-1/2 feet in well L1. Wells L2 and L3 also showed high water tables in relation to the other observation wells. All three of these wells were located in the landfill and completed in refuse. The other 11 wells were located on or adjacent to the landfill perimeter. There would appear to be evidence of groundwater mounding.

The water table appeared to fluctuate seasonally, with the highest water levels occurring in the spring or early summer. The wells located in the landfill, in general, responded to major precipitation events with a corresponding increase in water table elevation. No such generalization could be made for the other wells.

Because of agricultural and other land use restrictions, the 11 newer observation wells were placed immediately adjacent to the old landfill site. Not accounting for possible effects of groundwater mounding, the direction of shallow groundwater flow appeared to be in the south direction. Information from the North Dakota State Water Commission places the old Fargo landfill on the east edge of a cone of depression for a West Fargo, North Dakota, municipal well. Deep groundwater flow is in a southwest direction in response to the drawdown. A connection between

shallow groundwater systems and deep groundwater flow systems has not been established.

RECOMMENDATIONS

Based on the results obtained from the present study, recommendations for further study are suggested.

1. The evidence of contamination in several of the wells would indicate the need for additional monitoring wells to explore the lateral and vertical extent of the contamination.
2. It appears that the silty sand layer beneath the landfill acts as a separate shallow groundwater system. Groundwater samples taken from the wells screened at this layer show, in general, a higher degree of contamination than the other peripheral well sites. Additional wells screened at the silty sand layer are needed to examine more thoroughly the levels of contamination in this layer.
3. The occurrance of groundwater mounding at the old landfill site quite possibly affects the water table levels in the wells located within the landfill boundaries and around the periphery of the landfill. To better define the direction of flow of shallow groundwater, it is necessary to locate additional groundwater monitoring sites further from the landfill site to exclude the effects of mounding.
4. Observation well 3 showed an excessively high groundwater pH. Results of the present study show no obvious explanation for this condition. Additional study is needed to specifically identify the cause or causes of

the high pH values in well 3.

5. Unfiltered groundwater samples were used for mineral and trace metal analyses, the intent being to determine the maximum potential concentrations and their pollution potential. As a follow up, additional analysis of filtered groundwater samples is necessary to determine the soluble fraction of the metal concentrations. The soluble forms, being mobile, pose an immediate threat to groundwater contamination.

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APPENDIX I

North Dakota State Public Health Laboratory Procedures

APPENDIX I

1. Method for Chemical Analysis of Water and Wastes: EPA 600/4-79-020.

Parameter	Method
Total Alkalinity	310.1
Ammonia	350.1
Bicarbonate	310.1
Carbonate	310.1
pH	150.1
Sulfate	375.2
Total Phosphate	365.1
Ortho Phosphate	365.1
Conductivity	120.1
Total Kjeldahl Nitrogen	351.2
Nitrate	353.2

Element	Method
Calcium	215.1
Flouride	340.2
Iron	236.1
Magnesium	242.1
Manganese	243.1
Potassium	258.1
Sodium	273.1
Arsenic	206.2
Barium	208.1
Cadmium	213.2
Chromium	218.2
Copper	220.1
Lead	239.2
Selenium	270.3
Silver	272.2
Zinc	289.1

2. Standard Methods for the Examination of Water and Wastewater: 15th Edition, 1980.

Element	Method
Chloride	407A

3. Methods for Organic Chemical Analysis of Municipal and Industrial Wastewater: EPA-600/4-82-057.

Pesticide	Method
Endrin	608
Lindane	608
Methoxychlor	608
Toxaphene	608

4. Test Methods for Evaluating Solid Waste, Physical/Chemical Methods: EPA-SW-846, 2nd Edition, 1982.

Herbicide	Method
2, 4-D	8150
2, 4, 5-TP Silvex	8150

5. Other

Parameter	Method
Chemical Oxygen Demand	Hach micro method (dichromate reflux)
Total Hardness	calculated value
Percent Sodium	calculated value
Total Dissolved Solids	summation of major ions
Sodium Adsorption Ratio	calculated value

APPENDIX II

North Dakota State Public Health Laboratory Results

North Dakota State Department of Health
Public Health Laboratory
7/22/83

Cass County

Log Number: 83-C 4140

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A1)
Comments: Filtered version of Log Number: 83-C 3802

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity (CaCO3)	439.	mg/l
Bicarbonate (HCO3)	536.	mg/l
Calcium	242.	mg/l
Carbonate (CO3)	0.	mg/l
Total Hardness (as CaCO3)	861.	mg/l
Iron	0.03	mg/l
Magnesium	62.5	mg/l
Manganese	1.10	mg/l
pH	7.5	
Potassium	8.85	mg/l
Sodium	173.	mg/l
Percent Sodium	30.3	%
Total Dissolved Solids(C)	1050	mg/l
Sodium Adsorption Ratio	2.56	
Conductivity	1314.	umhos/cm

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Log Number: 83-C 3802

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A1)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity (CaCO3)	2480	mg/l
Ammonia (N)	0.974	mg/l
Bicarbonate (HCO3)	3030	mg/l
Calcium	1040	mg/l
Carbonate (CO3)	0.	mg/l
Chemical Oxygen Demand	761.	mg/l
Chloride	105.	mg/l
Fluoride	0.1	mg/l
Total Hardness (as CaCO3)	4000	mg/l
Iron	510.	mg/l
Magnesium	338.	mg/l
Manganese	21.0	mg/l
pH	7.6	
Potassium	20.0	mg/l
Sodium	192.	mg/l
Percent Sodium	9.4	%
Sulfate as (SO4)	877.	mg/l
Total Dissolved Solids(C)	4070	mg/l
Total Phosphate as (P)	0.069	mg/l
Ortho Phosphate as (P)	0.024	mg/l
Sodium Adsorption Ratio	1.32	
Conductivity	2013.	umhos/cm
Total Kjeldahl Nitrogen	16.1	mg/l
Nitrate as (N)	0.017	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Log Number: 83-C 3803

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A2)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity (CaCO3)	1230	mg/l
Ammonia (N)	0.419	mg/l
Bicarbonate (HCO3)	1500	mg/l
Calcium	568.	mg/l
Carbonate (CO3)	0.	mg/l
Chemical Oxygen Demand	216.	mg/l
Chloride	80.0	mg/l
Fluoride	0.2	mg/l
Total Hardness (as CaCO3)	1970	mg/l
Iron	39.4	mg/l
Magnesium	135.	mg/l
Manganese	7.32	mg/l
pH	7.6	
Potassium	13.1	mg/l
Sodium	323.	mg/l
Percent Sodium	26.2	%
Sulfate as (SO4)	1670	mg/l
Total Dissolved Solids(C)	3530	mg/l
Total Phosphate as (P)	0.037	mg/l
Ortho Phosphate as (P)	0.017	mg/l
Sodium Adsorption Ratio	3.17	
Conductivity	2926.	umhos/cm
Total Kjeldahl Nitrogen	3.90	mg/l
Nitrate as (N)	0.045	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ____________ Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Log Number: 83-C 3804

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A3)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity ($CaCO_3$)	5060	mg/l
Ammonia (N)	1.64	mg/l
Bicarbonate (HCO_3)	177.	mg/l
Calcium	1490	mg/l
Carbonate (CO_3)	2950	mg/l
Chemical Oxygen Demand	200.	mg/l
Chloride	205.	mg/l
Fluoride	0.0	mg/l
Total Hardness (as $CaCO_3$)	4820	mg/l
Iron	156.	mg/l
Magnesium	265.	mg/l
Manganese	13.6	mg/l
pH	12.0	
Potassium	198.	mg/l
Sodium	708.	mg/l
Percent Sodium	24.1	%
Sulfate as (SO_4)	1910	mg/l
Total Dissolved Solids(C)	7820	mg/l
Total Phosphate as (P)	0.091	mg/l
Ortho Phosphate as (P)	0.001	mg/l
Sodium Adsorption Ratio	4.44	
Conductivity	5355.	umhos/cm
Total Kjeldahl Nitrogen	8.14	mg/l
Nitrate as (N)	0.045	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Los Number: 83-C 3805

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Farso Landfill (# A4)

D. M. Griffin, Jr.
Civil Ensineering Dept.
NDSU
Farso, ND 58105

Chemical Analysis

Total Alkalinity (CaCO3)	1870	ms/1
Ammonia (N)	0.179	ms/1
Bicarbonate (HCO3)	2290	ms/1
Calcium	908.	ms/1
Carbonate (CO3)	0.	ms/1
Chemical Oxysen Demand	244.	ms/1
Chloride	345.	ms/1
Fluoride	0.1	ms/1
Total Hardness (as CaCO3)	4560	ms/1
Iron	174.	ms/1
Masnesium	558.	ms/1
Mansanese	27.8	ms/1
pH	8.0	
Potassium	17.4	ms/1
Sodium	1410	ms/1
Percent Sodium	40.1	%
Sulfate as (SO4)	5120	ms/1
Total Dissolved Solids(C)	9480	ms/1
Total Phosphate as (P)	0.085	ms/1
Ortho Phosphate as (P)	0.056	ms/1
Sodium Adsorption Ratio	9.09	
Conductivity	7807.	umhos/cm
Total Kjeldahl Nitrosen	6.83	ms/1
Nitrate as (N)	0.009	ms/1

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Karl Reitz Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Log Number: 83-C 3806

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A5)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity ($CaCO_3$)	857.	mg/l
Ammonia (N)	0.716	mg/l
Bicarbonate (HCO_3)	1050	mg/l
Calcium	580.	mg/l
Carbonate (CO_3)	0.	mg/l
Chemical Oxygen Demand	530.	mg/l
Chloride	200.	mg/l
Fluoride	0.1	mg/l
Total Hardness (as $CaCO_3$)	2170	mg/l
Iron	91.0	mg/l
Magnesium	175.	mg/l
Manganese	9.85	mg/l
pH	7.8	
Potassium	15.0	mg/l
Sodium	439.	mg/l
Percent Sodium	30.5	%
Sulfate as (SO_4)	2000	mg/l
Total Dissolved Solids(C)	3930	mg/l
Total Phosphate as (P)	0.081	mg/l
Ortho Phosphate as (P)	0.062	mg/l
Sodium Adsorption Ratio	4.10	
Conductivity	3441.	umhos/cm
Total Kjeldahl Nitrogen	4.64	mg/l
Nitrate as (N)	0.008	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Retz Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83 Cass County

Log Number: 83-C 3807

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A6)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity ($CaCO_3$)	560.	mg/l
Ammonia (N)	0.882	mg/l
Bicarbonate (HCO_3)	684.	mg/l
Calcium	510.	mg/l
Carbonate (CO_3)	0.	mg/l
Chemical Oxygen Demand	55.	mg/l
Chloride	260.	mg/l
Fluoride	0.1	mg/l
Total Hardness (as $CaCO_3$)	1910	mg/l
Iron	0.73	mg/l
Magnesium	155.	mg/l
Manganese	4.36	mg/l
pH	7.7	
Potassium	10.6	mg/l
Sodium	560.	mg/l
Percent Sodium	38.8	%
Sulfate as (SO_4)	2600	mg/l
Total Dissolved Solids(C)	4430	mg/l
Total Phosphate as (P)	0.017	mg/l
Ortho Phosphate as (P)	0.009	mg/l
Sodium Adsorption Ratio	5.56	
Conductivity	4417.	umhos/cm
Total Kjeldahl Nitrogen	0.884	mg/l
Nitrate as (N)	0.008	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Kat Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83 Cass County

Log Number: 83-C 3808

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A7)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity (CaCO3)	901.	mg/l
Ammonia (N)	0.714	mg/l
Bicarbonate (HCO3)	1100	mg/l
Calcium	548.	mg/l
Carbonate (CO3)	0.	mg/l
Chemical Oxygen Demand	369.	mg/l
Chloride	400.	mg/l
Fluoride	0.1	mg/l
Total Hardness (as CaCO3)	2070	mg/l
Iron	56.5	mg/l
Magnesium	170.	mg/l
Manganese	9.30	mg/l
pH	7.8	
Potassium	14.9	mg/l
Sodium	412.	mg/l
Percent Sodium	30.2	%
Sulfate as (SO4)	1690	mg/l
Total Dissolved Solids(C)	3770	mg/l
Total Phosphate as (P)	0.074	mg/l
Ortho Phosphate as (P)	0.052	mg/l
Sodium Adsorption Ratio	3.94	
Conductivity	10120	umhos/cm
Total Kjeldahl Nitrogen	4.42	mg/l
Nitrate as (N)	0.008	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ______________ Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Log Number: 83-C 3809

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A8)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity (CaCO3)	602.	mg/l
Ammonia (N)	0.569	mg/l
Bicarbonate (HCO3)	735.	mg/l
Calcium	412.	mg/l
Carbonate (CO3)	0.	mg/l
Chemical Oxygen Demand	97.	mg/l
Chloride	265.	mg/l
Fluoride	0.1	mg/l
Total Hardness (as CaCO3)	1490	mg/l
Iron	6.70	mg/l
Magnesium	112.	mg/l
Manganese	2.47	mg/l
pH	7.9	
Potassium	10.5	mg/l
Sodium	250.	mg/l
Percent Sodium	26.5	%
Sulfate as (SO4)	1500	mg/l
Total Dissolved Solids(C)	2910	mg/l
Total Phosphate as (P)	0.027	mg/l
Ortho Phosphate as (P)	0.024	mg/l
Sodium Adsorption Ratio	2.81	
Conductivity	2990.	umhos/cm
Total Kjeldahl Nitrogen	1.74	mg/l
Nitrate as (N)	0.097	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Kretz Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Log Number: 83-C 3810

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A9)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity (CaCO3)	1110	mg/l
Ammonia (N)	0.760	mg/l
Bicarbonate (HCO3)	1350	mg/l
Calcium	605.	mg/l
Carbonate (CO3)	0.	mg/l
Chemical Oxygen Demand	97.	mg/l
Chloride	850.	mg/l
Fluoride	0.2	mg/l
Total Hardness (as CaCO3)	3100	mg/l
Iron	15.0	mg/l
Magnesium	385.	mg/l
Manganese	6.46	mg/l
pH	7.8	
Potassium	18.4	mg/l
Sodium	1120	mg/l
Percent Sodium	44.0	%
Sulfate as (SO4)	3410	mg/l
Total Dissolved Solids(C)	7210	mg/l
Total Phosphate as (P)	0.034	mg/l
Ortho Phosphate as (P)	0.021	mg/l
Sodium Adsorption Ratio	8.77	
Conductivity	7751.	umhos/cm
Total Kjeldahl Nitrogen	1.55	mg/l
Nitrate as (N)	33.0	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Log Number: 83-C 3811

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A10)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity ($CaCO_3$)	494.	mg/l
Ammonia (N)	0.539	mg/l
Bicarbonate (HCO_3)	603.	mg/l
Calcium	490.	mg/l
Carbonate (CO_3)	0.	mg/l
Chemical Oxygen Demand	145.	mg/l
Chloride	300.	mg/l
Fluoride	0.1	mg/l
Total Hardness (as $CaCO_3$)	1810	mg/l
Iron	7.28	mg/l
Magnesium	142.	mg/l
Manganese	4.12	mg/l
pH	7.8	
Potassium	9.00	mg/l
Sodium	464.	mg/l
Percent Sodium	35.7	%
Sulfate as (SO_4)	2720	mg/l
Total Dissolved Solids(C)	4420	mg/l
Total Phosphate as (P)	0.038	mg/l
Ortho Phosphate as (P)	0.013	mg/l
Sodium Adsorption Ratio	4.74	
Conductivity	4482.	umhos/cm
Total Kjeldahl Nitrogen	0.758	mg/l
Nitrate as (N)	0.029	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Log Number: 83-C 3812

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# A11)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity (CaCO3)	332.	mg/l
Ammonia (N)	0.580	mg/l
Bicarbonate (HCO3)	405.	mg/l
Calcium	79.0	mg/l
Carbonate (CO3)	0.	mg/l
Chemical Oxygen Demand	33.	mg/l
Chloride	80.0	mg/l
Fluoride	0.6	mg/l
Total Hardness (as CaCO3)	272.	mg/l
Iron	0.92	mg/l
Magnesium	18.0	mg/l
Manganese	0.246	mg/l
pH	8.2	
Potassium	7.15	mg/l
Sodium	83.0	mg/l
Percent Sodium	39.8	%
Sulfate as (SO4)	109.	mg/l
Total Dissolved Solids(C)	576.	mg/l
Total Phosphate as (P)	0.036	mg/l
Ortho Phosphate as (P)	0.013	mg/l
Sodium Adsorption Ratio	2.19	
Conductivity	824.	umhos/cm
Total Kjeldahl Nitrogen	0.226	mg/l
Nitrate as (N)	0.020	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Log Number: 83-C 3799

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# AL1)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity (CaCO3)	1810	mg/l
Ammonia (N)	103.	mg/l
Bicarbonate (HCO3)	2200	mg/l
Calcium	135.	mg/l
Carbonate (CO3)	0.	mg/l
Chemical Oxygen Demand	492.	mg/l
Chloride	850.	mg/l
Fluoride	0.1	mg/l
Total Hardness (as CaCO3)	1140	mg/l
Iron	18.6	mg/l
Magnesium	195.	mg/l
Manganese	0.835	mg/l
pH	7.5	
Potassium	83.8	mg/l
Sodium	608.	mg/l
Percent Sodium	53.6	%
Sulfate as (SO4)	89.	mg/l
Total Dissolved Solids(C)	3050	mg/l
Total Phosphate as (P)	0.131	mg/l
Ortho Phosphate as (P)	0.085	mg/l
Sodium Adsorption Ratio	7.84	
Conductivity	5124.	umhos/cm
Total Kjeldahl Nitrogen	3.06	mg/l
Nitrate as (N)	0.009	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
7/27/83

Cass County

Log Number: 83-C 3800

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# AL2)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity (CaCO3)	3300	mg/l
Ammonia (N)	470.	mg/l
Bicarbonate (HCO3)	4030	mg/l
Calcium	74.0	mg/l
Carbonate (CO3)	0.	mg/l
Chemical Oxygen Demand	1000	mg/l
Chloride	3250	mg/l
Fluoride	0.1	mg/l
Total Hardness (as CaCO3)	1090	mg/l
Iron	26.2	mg/l
Magnesium	221.	mg/l
Manganese	0.232	mg/l
pH	7.7	
Potassium	284.	mg/l
Sodium	1690	mg/l
Percent Sodium	77.0	%
Sulfate as (SO4)	21.	mg/l
Total Dissolved Solids(C)	7530	mg/l
Total Phosphate as (P)	0.416	mg/l
Ortho Phosphate as (P)	0.392	mg/l
Sodium Adsorption Ratio	22.2	
Conductivity	11240	umhos/cm
Total Kjeldahl Nitrogen	299.	mg/l
Nitrate as (N)	0.010	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Ral Ref Chemist

North Dakota State Department of Health
Public Health Laboratory
7/28/83

Cass County

Log Number: 83-C 3801

Date Collected: 6/15/83 Date Received: 6/16/83

Source: Old Fargo Landfill (# AL3)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Total Alkalinity ($CaCO_3$)	5930	mg/l
Ammonia (N)	327.	mg/l
Bicarbonate (HCO_3)	7240	mg/l
Calcium	69.5	mg/l
Carbonate (CO_3)	0.	mg/l
Chemical Oxygen Demand	1030	mg/l
Chloride	1050	mg/l
Fluoride	0.1	mg/l
Total Hardness (as $CaCO_3$)	1890	mg/l
Iron	15.5	mg/l
Magnesium	418.	mg/l
Manganese	0.132	mg/l
pH	7.8	
Potassium	301.	mg/l
Sodium	1580	mg/l
Percent Sodium	64.5	%
Sulfate as (SO_4)	39.	mg/l
Total Dissolved Solids(C)	7030	mg/l
Total Phosphate as (P)	1.18	mg/l
Ortho Phosphate as (P)	1.00	mg/l
Sodium Adsorption Ratio	15.8	
Conductivity	10130	umhos/cm
Total Kjeldahl Nitrogen	156.	mg/l
Nitrate as (N)	0.029	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Recd Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83 Cass County

Log Number: 83-C 4497

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# B1)

D. H. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	142.	ug/l
Barium	130.	ug/l
Cadmium	31.6	ug/l
Chromium	580.	ug/l
Copper (Flame AA)	875.	ug/l
Lead	300.	ug/l
Selenium (Hydride)	5.10	ug/l
Silver	0.12	ug/l
Zinc	1940	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Re[illegible] Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83 Cass County

Log Number: 83-C 4488

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# B2)

R. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	12.6	ug/l
Barium	90.	ug/l
Cadmium	4.26	ug/l
Chromium	17.4	ug/l
Copper (Flame AA)	40.	ug/l
Lead	19.5	ug/l
Selenium (Hydride)	0.25	ug/l
Silver	0.13	ug/l
Zinc	82.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz _______________ Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83

Cass County

Log Number: 83-C 4489

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# B3)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	24.7	ug/l
Barium	130.	ug/l
Cadmium	1.08	ug/l
Chromium	52.0	ug/l
Copper (Flame AA)	46.	ug/l
Lead	28.8	ug/l
Selenium (Hydride)	0.89	ug/l
Silver	0.17	ug/l
Zinc	98.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Roz_____________ Chemist

AD-A157 285 FARGO-MOORHEAD URBAN STUDY WATER SUPPLY APPENDIX VOLUME 3 PHASE 2 ATTACHM..(U) CORPS OF ENGINEERS ST PAUL MN ST PAUL DISTRICT MAY 85 2/2

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North Dakota State Department of Health
Public Health Laboratory
9/26/83 Cass County

Lab Number: 83-C 4490

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# B4)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	30.4	ug/l
Barium	10.	ug/l
Cadmium	2.92	ug/l
Chromium	43.8	ug/l
Copper (Flame AA)	32.	ug/l
Lead	30.7	ug/l
Selenium (Hydride)	0.00	ug/l
Silver	0.06	ug/l
Zinc	370.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83 Cass County

Lab Number: 83-C 4491

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# B5)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	12.9	ug/l
Barium	70.	ug/l
Cadmium	1.38	ug/l
Chromium	17.4	ug/l
Copper (Flame AA)	23.	ug/l
Lead	14.0	ug/l
Selenium (hydride)	0.17	ug/l
Silver	0.22	ug/l
Zinc	58.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz _______________ Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83

Cass County

Lab Number: 83-C 4492

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# B6)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	14.2	ug/l
Barium	40.	ug/l
Cadmium	0.88	ug/l
Chromium	4.61	ug/l
Copper (Flame AA)	20.	ug/l
Lead	7.2	ug/l
Selenium (Hydride)	0.08	ug/l
Silver	0.11	ug/l
Zinc	40.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reff Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83

Cass County

Log Number: 83-C 4493

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill(# B7)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	25.1	ug/l
Barium	150.	ug/l
Cadmium	1.52	ug/l
Chromium	29.4	ug/l
Copper (Flame AA)	56.	ug/l
Lead	18.2	ug/l
Selenium (Hydride)	0.68	ug/l
Silver	0.00	ug/l
Zinc	89.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Roy ______________ Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83

Cass County

Log Number: 83-C 4494

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# 38)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	18.1	ug/l
Barium	130.	ug/l
Cadmium	1.25	ug/l
Chromium	8.60	ug/l
Copper (Flame AA)	28.	ug/l
Lead	11.2	ug/l
Selenium (Hydride)	0.00	ug/l
Silver	0.00	ug/l
Zinc	68.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reff Chemist

North Dakota State Department of Health
Public Health Laboratory
7/25/83
Cass County

Log Number: 83-C 4495

Date Collected: 7/19/73 Date Received: 7/20/83

Source: Old Fargo Landfill (# B9)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	33.5	ug/l
Barium	90.	ug/l
Cadmium	3.23	ug/l
Chromium	34.7	ug/l
Copper (Flame AA)	65.	ug/l
Lead	52.4	ug/l
Selenium (Hydride)	0.21	ug/l
Silver	0.20	ug/l
Zinc	1470	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83 Cass County

Log Number: 83-C 4496

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# B10)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	16.8	ug/l
Barium	60.	ug/l
Cadmium	0.74	ug/l
Chromium	3.48	ug/l
Copper (Flame AA)	12.	ug/l
Lead	2.9	ug/l
Selenium (Hydride)	0.00	ug/l
Silver	0.00	ug/l
Zinc	43.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Raaz Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83

Cass County

Lab Number: 83-C 4497

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# B11)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	14.8	ug/l
Barium	40.	ug/l
Cadmium	0.74	ug/l
Chromium	4.94	ug/l
Copper (Flame AA)	7.	ug/l
Lead	4.6	ug/l
Selenium (Hydride)	0.06	ug/l
Silver	0.00	ug/l
Zinc	24.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Renz Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83

Cass County

Log Number: 83-C 4498

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# 812) Pond

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	24.3	ug/l
Barium	170.	ug/l
Cadmium	0.00	ug/l
Chromium	11.5	ug/l
Copper (Flame AA)	1.	ug/l
Lead	2.5	ug/l
Selenium (Hydride)	0.00	ug/l
Silver	0.00	ug/l
Zinc	27.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
9/26/83 Cass County

Log Number: 83-C 4499

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# B13) **Duplicate of #B8**

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	16.5	ug/l
Barium	130.	ug/l
Cadmium	1.16	ug/l
Chromium	8.60	ug/l
Copper (Flame AA)	30.	ug/l
Lead	15.6	ug/l
Selenium (Hydride)	0.00	ug/l
Silver	0.07	ug/l
Zinc	79.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reiz Chemist

North Dakota State Department of Health
Public Health Laboratory
[illegible] [illegible] County

Log Number: 83-C 4500

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# BL1)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	18.7	ug/l
Barium	360.	ug/l
Cadmium	0.80	ug/l
Chromium	8.43	ug/l
Copper (Flame AA)	26.	ug/l
Lead	64.6	ug/l
Selenium (Hydride)	0.00	ug/l
Silver	0.07	ug/l
Zinc	152.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Retz Chemist

North Dakota State Department of Health

Public Health Laboratory

9/26/83 Cass County

Log Number: 83-C 4501

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# BL2)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	21.3	ug/l
Barium	1220	ug/l
Cadmium	1.09	ug/l
Chromium	17.8	ug/l
Copper (Flame AA)	17.	ug/l
Lead	68.5	ug/l
Selenium (Hydride)	0.00	ug/l
Silver	0.00	ug/l
Zinc	148.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
[illegible] [illegible]

Log [illegible]: 83-C 4502

Date Collected: 7/19/83 Date Received: 7/20/83

Source: Old Fargo Landfill (# BL3)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Arsenic	16.3	ug/l
[illegible]	920.	ug/l
Cadmium	2.38	ug/l
Chromium	23.4	ug/l
Copper (Flame AA)	16.	ug/l
Lead	45.8	ug/l
Selenium (Hydride)	0.03	ug/l
Silver	0.00	ug/l
Zinc	326.	ug/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz ---------------- Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83

Cass County

Log Number: 83-C 4771

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B1

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.1	mg/l
Nitrate as (N)	0.017	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Roaly Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83

Cass County

Log Number: 83-C 4772

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B2

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.1	mg/l
Nitrate as (N)	0.491	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Reed Kott Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83

Cass County

Log Number: 83-C 4773

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B3

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.1	mg/l
Nitrate as (N)	0.079	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ____________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83

Cass County

Log Number: 83-C 4774

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B4

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.1	mg/l
Nitrate as (N)	0.020	mg/l
Endrin	None Detected	
Lindane	< 1.0	ug/l
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ______________ Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83

Cass County

Log Number: 83-C 4775

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B5

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.1	mg/l
Nitrate as (N)	0.019	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Roy Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83

Cass County

Log Number: 83-C 4776

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B6

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.1	mg/l
Nitrate as (N)	0.014	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Riz Chemist

North Dakota State Department of Health
Public Health Laboratory
8/ 9/83

Cass County

Log Number: 83-C 4823

Date Collected: 7/26/83 Date Received: 7/29/83

Source: Unidentified Bottle (B7 ?)

D. M. Griffin Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.3	mg/l

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Ree Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83 Cass County

Log Number: 83-C 4777

Date Collected: 7/26/83 Date Received: 7/29/83

Source: 87
Comments: No marked Fluoride cont.

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Nitrate as (N)	2.82	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Kerz Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83 Cass County

Log Number: 83-C 4778

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B8

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.1	mg/l
Nitrate as (N)	0.044	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Ring Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83 Cass County

Log Number: 83-C 4779

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B9

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.2	mg/l
Nitrate as (N)	12.8	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Ree[illegible] Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83 Cass County

Log Number: 83-C 4780

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B10

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.1	mg/l
Nitrate as (N)	0.018	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Kurtz Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83 Cass County

Log Number: 83-C 4781

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B11

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.6	mg/l
Nitrate as (N)	0.012	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Resz Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83

Cass County

Log Number: 83-C 4782

Date Collected: 7/26/83 Date Received: 7/29/83

Source: B12 (Pond)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	1.3	mg/l
Nitrate as (N)	0.012	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. [signature] Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83 Cass County

Log Number: 83-C 4768

Date Collected: 7/26/83 Date Received: 7/29/83

Source: BL1

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.2	mg/l
Nitrate as (N)	0.036	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83

Cass County

Log Number: 83-C 4769

Date Collected: 7/26/83 Date Received: 7/29/83

Source: BL2

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.1	mg/1
Nitrate as (N)	0.024	mg/1
Endrin	None Detected	
Lindane	< 0.2	ug/1
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ______________ Chemist

North Dakota State Department of Health
Public Health Laboratory
8/22/83

Cass County

Log Number: 83-C 4770

Date Collected: 7/26/83 Date Received: 7/29/83

Source: BL3

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Fluoride	0.1	mg/l
Nitrate as (N)	0.026	mg/l
Endrin	None Detected	
Lindane	None Detected	
Methoxychlor	None Detected	
Toxaphene	None Detected	

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. Rod Reetz Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83 Cass County

Log Number: 83-C 5499

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C1

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ______________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5500

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C2

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ______________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Lon Number: 83-C 5501

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C3

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ______________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5502

Date Collected: 8/22/83   Date Received: 8/25/83

Source: C4

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ____________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5503

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C5

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ____________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5504

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C6

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5505

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C7

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ____________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83 Cass County

Log Number: 83-C 5506

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C8

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5507

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C9

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ____ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5508

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C10

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ______ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5509

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C11

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83 Cass County

Log Number: 83-C 5310

Date Collected: 8/22/83 Date Received: 8/25/83

Source: C12 (Pond)

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5496

Date Collected: 8/22/83 Date Received: 8/25/83

Source: CL1

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ______________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5497

Date Collected: 8/22/83 Date Received: 8/25/83

Source: CL2

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ______________________ Chemist

North Dakota State Department of Health
Public Health Laboratory
10/13/83

Cass County

Log Number: 83-C 5498

Date Collected: 8/22/83 Date Received: 8/25/83

Source: CL3

D. M. Griffin, Jr.
Civil Engineering Dept.
NDSU
Fargo, ND 58105

Chemical Analysis

Endrin	None detected	10/13/83	KW
Lindane	None detected	10/13/83	KW
Methoxychlor	None detected	10/13/83	KW
Toxaphene	None detected	10/13/83	KW
2,4-D	None detected	10/13/83	KW
2,4,5-TP Silvex	None detected	10/13/83	KW

For any further information, write to:
The State Department of Health, Bismarck, ND 58505

Per. ______________ Chemist

APPENDIX III

Old Fargo Landfill Test Boring Logs

SUBSURFACE EXPLORATION PROGRAM

AND OBSERVATION WELL INSTALLATION

OLD FARGO LANDFILL

FARGO, ND

#53-1456

twin city testing

twin city testing
and engineering laboratory, inc.
2105 7th AVE NO
FARGO ND 58102
PHONE 701/235-4256

January 13, 1983

CHARLES W. BRITZIUS, P.E.
Chairman of the Board
NORMAN E. HENNING, P.E.
President
CLINTON R. EUE
Executive Vice-President/
Treasurer
ALBERT C. HOLLER, F.A.I.C.
Vice-President Chemistry

Dr. Dixie Griffin
Department of Civil Engineering
NDSU
Fargo, ND 58105

Gentlemen

Subj: Subsurface Exploration Program and
Observation Well Installation
Old Fargo Landfill
Fargo, ND
#53-1456

Ten observation wells were installed adjacent to the old landfill in Fargo. Soil samples were taken at eight of the observation well sites. This work was conducted in accordance with our proposal letter dated October 22, 1982 and your verbal authorization of December 16, 1982. *The purpose of this report is to present the results of the* subsurface exploration program and to present pertinent information concerning the observation wells.

The test borings were performed according to the procedure described by ASTM:D1586-67. Soil sampling and classification were performed in accordance with ASTM:D2488-69. The soil samples will be retained at this office for a period of about one month unless we are notified further as to their disposition.

The borings were put down at locations previously selected by you and as shown on the attached sketch. Surface elevations were referenced to the top of the fire hydrant located at the southeast corner of the old landfill and also as shown on the attached sketch. The top of the hydrant was assumed to be at an elevation of 100.0'.

A review of the boring logs suggests that there is fill and/or topsoil located at the surface, with the fill depth being quite variable. Some garbage was encountered in a few of the borings. The fill and/or topsoil is underlain by brown and gray mottled fat clay which extends to a nominal depth of 14' and is underlain by fine grained silty sand. The silty sand stratum is quite variable in thickness, ranging from as little as 1½' to as much as 8' or 9'. The sand is underlain by gray fat clay which then extends to the termination depth of the borings (maximum 51').

ST. PAUL, ROCHESTER, MANKATO MN; BISMARCK, FARGO, GRAND FORKS, MINOT ND; RAPID CITY, SIOUX FALLS SD; WATERLOO IA; APPLETON, EAU CLAIRE, LACROSSE, WAUSAU, WI; CASPER, GILLETTE WY

The penetration resistance ("N" value) indicates that the fat clay above the sand is medium to rather stiff in consistency, whereas, the fat clay below the sand generally grades from a medium to soft consistency. The sand is quite variable in density, ranging from loose to very dense.

Ground water measurements taken during drilling or, after the test borings had been completed, generally suggest a water level of 11 to 15' below grade. We wish to point out that water level checks taken in relatively impervious soils, such as the clay encountered at this site, generally require a relatively large amount of observation time to accurately establish the static ground water level. This amount of time was not available during the scope of the boring program. Continued monitoring of the observation wells should be performed to determine actual ground water levels. Also, yearly and seasonal fluctuations, either upward or downward, can occur in the water level.

The observation wells installed consisted of 2" PVC screen at the bottom, from 5' to 10' in length, and 2" schedule 40 PVC pipe extending above the screen to a distance of 2' to 3' above ground elevation. A layer of cheesecloth wrapping was placed around the screens and they were backfilled using 45 to 55 mm diameter filter sand. Above the filter sand, grout consisting of 3 parts cement and 2 parts bentonite was used to backfill the borings to the ground surface. Four inch diameter steel casing was then placed over the PVC standpipe for protection and locks and caps were provided. Depths of the observation wells are tabulated as noted below:

Well Number	Depth to Bottom of Screen
1	50'
2	30'
3	23'
4	25'
5	30'
6	35'
7	35'
8	35'
9	30'
10	35'

Because the area of the borings in relation to the entire area is very small, and for other reasons, we do not warrant conditions below the depths of our borings, or that the strata logged from our borings are necessarily typical of the entire site.

If we can be of assistance during the sampling and chemical testing phase of the work, please do not hesitate to contact us.

TWIN CITY TESTING AND
ENGINEERING LABORATORY, INC.

Joel A. Zeltinger

Joel A. Zeltinger, P.E.
Geotechnical Engineer

JAZ:af

JOEL A. ZELTINGER
REGISTERED
PROFESSIONAL
PE-2612
ENGINEER
NORTH DAKOTA

LOG OF TEST BORING

JOB NO 53-1456 VERTICAL SCALE 1" = 5' BORING NO 1

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

DEPTH IN FEET	DESCRIPTION OF MATERIAL SURFACE ELEVATION 97.4'	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	LABORATORY TESTS W	D	[illegible]	Qu
	FAT CLAY, black, frozen (OH)	TOPSOIL			1	FA				
1½	FAT CLAY, grayish brown, medium, a few lime pockets (CH)	LAKE AGASSIZ DEPOSITS	7		2	SB				
4	FAT CLAY, brown and gray mottled, rather stiff to medium, lenses and layers of silt (CH)		11		3	SB				
			6		4	SB				
			6		5	SB				
			5		6	SB				
15½	SILTY SAND, fine grained, grayish brown, wet, very loose (SP-SM)	COARSE ALLUVIUM	7		7	SB				
			5		8	SB				
23	FAT CLAY, gray, soft (CH)	LAKE AGASSIZ DEPOSITS	2		9	SB				
			4		10	SB				
			3		11	SB				
40										

CONTINUED ON NEXT PAGE

LOG OF TEST BORING

JOB NO. 53-1456 VERTICAL SCALE 1" = 5' BORING NO 1 Cont.

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
40	FAT CLAY CONTINUED	LAKE AGASSIZ DEPOSITS CONTINUED	4		12	SB				
			4		13	SB				
			4		14	SB				
51	END OF BORING									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
12:20	2:15	16'	14½'	15.7'	to	15.5'
12:20	3:45	51'	49½'	51'	to	16.6'
					to	
					to	

START 12-20-82 COMPLETE 12-20-82

METHOD 3¼" HSA 0-49½' @ 3:45

CREW CHIEF ZAK

SE 2-77-B-5

twin city testing and engineering laboratory, inc.

LOG OF TEST BORING

JOB NO 53-1456 VERTICAL SCALE 1" = 5' BORING NO 4

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

SURFACE ELEVATION 102.5'

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
	FILL, mostly FAT CLAY, grayish brown, a little sand, frozen to 1½'	FILL			1	FA				
			14		2	SB				
4	GARBAGE		42		3	SB				
			13		4	SB				
10	FAT CLAY, brown and gray mottled, rather stiff to medium, layers and lenses of silt (CH)	LAKE AGASSIZ DEPOSITS	13		5	SB				
			7		6	SB				
			7		7	SB				
18½	SILTY SAND, fine grained, grayish brown, wet, very dense (SP-SM)	COARSE ALLUVIUM	43		8	SB				
23	FAT CLAY, brownish gray, rather stiff (CH)	LAKE AGASSIZ DEPOSITS	15		9	SB				
26	END OF BORING									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
12-22	11:15	21'	19½'	21'	to	18'
12-22	11:30	26'	24½'	26'	to	None
					to	
					to	

START 12-22-82 COMPLETE 12-22-82

METHOD 3¼" HSA 0-24½' @ 11:30

CREW CHIEF ZAK

twin city testing and engineering laboratory, inc.

LOG OF TEST BORING

JOB NO 53-1456 VERTICAL SCALE 1" = 5' BORING NO 5

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

DEPTH IN FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION 97.7')	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
	FILL, mostly FAT CLAY, brown and black mixed, frozen to 1½'	FILL			1	FA				
			10		2	SB				
3½	FAT CLAY, brown and gray mottled, rather stiff to medium, lenses and layers of silt (CH)	LAKE AGASSIZ DEPOSITS	10		3	SB				
			7		4	SB				
			7		5	SB				
			6		6	SB				
14	SILTY SAND, fine grained, grayish brown, wet, loose (SP-SM)	COARSE ALLUVIUM	6		7	SB				
17½	FAT CLAY, gray, rather stiff to soft to medium (CH)	LAKE AGASSIZ DEPOSITS	10		8	SB				
			4		9	SB				
			5		10	SB				
31	END OF BORING									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
12-22	1:45	16'	14½'	16'	to	15.6'
12-22	2:20	31'	29½'	31'	to	None
					to	
					to	

START 12-22-82 COMPLETE 12-22-82

METHOD 3½" HSA 0-29½' @ 2:15

CREW CHIEF ZAK

SE 7-77-8 -5

twin city testing and engineering laboratory, inc.

LOG OF TEST BORING

JOB NO 53-1456 VERTICAL SCALE 1" = 5' BORING NO 6

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

SURFACE ELEVATION 97.8'

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
	FILL, mostly FAT CLAY, brown, gray and black, frozen to 1½'	FILL			1	FA				
			5		2	SB				
			2		3	SB				
			2		4	SB				
9	FAT CLAY, brown and gray mottled, medium, lenses and layers of silt *	LAKE AGASSIZ DEPOSITS	5		5	SB				
11	FAT CLAY, gray, medium, lenses and layers of silt (CH)		5		6	SB				
14	SILTY SAND, fine grained, grayish brown, wet, dense (SP-SM)	COARSE ALLUVIUM	25		7	SB				MA
17	FAT CLAY, gray, medium to soft (CH)	LAKE AGASSIZ DEPOSITS	6		8	SB				
			3		9	SB				
			3		10	SB				
			4		11	SB				
36	END OF BORING									
	* (CH)									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
12-27	10:45	16'	14½'	16'	to	15.2'
12-27	11:35	36'	34½'	36'	to	32.0'
					to	
					to	

START 12-27-82 COMPLETE 12-27-82

METHOD 3¼" HSA 0-34½' @ 11:35

CREW CHIEF Miller

SE 2 ??-B 5

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LOG OF TEST BORING

JOB NO 53-1456 VERTICAL SCALE 1" = 5' BORING NO 7

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

DEPTH IN FEET	DESCRIPTION OF MATERIAL (SURFACE ELEVATION 101.8')	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
	FILL, mostly FAT CLAY, brown, black and gray mixed, frozen to 1½'	FILL			1	FA				
			5		2	SB				
			5		3	SB				
7	FAT CLAY, brownish gray, rather stiff (CH)	LAKE AGASSIZ DEPOSITS	12		4	SB				
9	FAT CLAY, brown and gray mottled, medium, lenses and layers of silt (CH)		8		5	SB				
			8		6	SB				
			6		7	SB				
18	SILTY SAND, fine grained, grayish brown, wet, loose - (SP-SM)	COARSE ALLUVIUM								
20½	FAT CLAY, gray, medium to soft (CH)	LAKE AGASSIZ DEPOSITS	6		8	SB				
			8		9	SB				
			3		10	SB				
			3		11	SB				
36	END OF BORING									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
12-27	3:45	21'	19½'	21'	to	18.5'
12-28	9:15	36'	34½'	36'	to	28.8'
					to	
					to	

START 12-27-82 COMPLETE 12-28-82

METHOD 3¼" HSA 0-34½' @ 11:10

CREW CHIEF Miller

LOG OF TEST BORING

JOB NO 53-1456 VERTICAL SCALE 1" = 5' BORING NO 8

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

DEPTH IN FEET	DESCRIPTION OF MATERIAL SURFACE ELEVATION 97.7'	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
	FILL, mostly FAT CLAY, brown, black and gray mixed, frozen to 1½'	FILL			1	FA				
4			8		2	SB				
6½	FAT CLAY, brown mottled, rather stiff (CH)	LAKE AGASSIZ DEPOSITS	9		3	SB				
	FAT CLAY, brown and gray mottled, rather stiff to medium, lenses and layers of silt (CH)		9		4	SB				
			5		5	SB				
14			6		6	SB				
16	SILTY SAND, fine grained, grayish brown, wet, medium dense (SP-SM)	COARSE ALLUVIUM	10		7	SB				
	FAT CLAY, gray, medium to soft (CH)	LAKE AGASSIZ DEPOSITS	5		8	SB				
			3		9	SB				
			3		10	SB				
36			4		11	SB				
	END OF BORING									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
12-29	11:00	16'	14½'	16'	to	14.5'
12-29	11:45	36'	34½'	36'	to	None
					to	
					to	

START 12-29-82 COMPLETE 12-29-82

METHOD 3¼" HSA 0-34½' @ 11:40

CREW CHIEF Miller

SE 2 :77-8 -3

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LOG OF TEST BORING

JOB NO 53-1456 VERTICAL SCALE 1" = 5' BORING NO 9

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

SURFACE ELEVATION 102.5'

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
	FILL, mostly FAT CLAY, brown, black and gray mixed, frozen to 1½'	FILL			1	FA				
			15		2	SB				
			11		3	SB				
6½	GARBAGE		38		4	SB				
			100/0.3		5	SB				
			100/0.2		6	SB				
15	FAT CLAY, brown and gray mottled, stiff, lenses and layers of silt (CH)	LAKE AGASSIZ DEPOSITS	25		7	SB				
18	SILTY SAND, fine grained, grayish brown, wet, very dense (SP-SM)	COARSE ALLUVIUM	* 100/0.5		8	SB				
			40		9	SB				
28	FAT CLAY, gray, medium (CH)	LAKE AGASSIZ DEPOSITS	6		10	SB				
31	END OF BORING									

* No recovery

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
12-28	2:00	21'	19½'	21'	to	19.1'
12-28	9:00	31'	29½'	30	to	19.0'
					to	
					to	

START 12-28-82 COMPLETE 12-29-82

METHOD 3¼" HSA 0-29½' @ 10:00

CREW CHIEF Miller

LOG OF TEST BORING

JOB NO 53-1456 VERTICAL SCALE 1" = 5' BORING NO 10

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

SURFACE ELEVATION 95.0'

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
2	FILL, mostly FAT CLAY, black and brown mixed, frozen to 1½'	FILL			1	FA				
	FAT CLAY, brown and gray mottled, rather stiff to medium, lenses of silt (CH)	LAKE AGASSIZ DEPOSITS	10		2	SB				
			9		3	SB				
			7		4	SB				
			8		5	SB				
13			10		6	SB				
	SILTY SAND, fine grained, grayish brown, wet, medium dense to very dense (SP-SM)	COARSE ALLUVIUM	42		7	SB				
21½			32		8	SB				
	FAT CLAY, gray, soft to medium (CH)	LAKE AGASSIZ DEPOSITS	3		9	SB				
			4		10	SB				
36			5		11	SB				
	END OF BORING									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
1-4	11:15	16'	14½'	15'	to	11.3'
1-4	12:15	36'	34½'	36'	to	31.5'
					to	
					to	

START 1-4-83 COMPLETE 1-4-83

METHOD 3¼" HSA 0-34½' @ 12:15

CREW CHIEF ZAK

SL-2177-B -5

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LOG OF TEST BORING

JOB NO 53-1569 VERTICAL SCALE 1" = 4' BORING NO 11

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

DEPTH IN FEET	DESCRIPTION OF MATERIAL SURFACE ELEVATION	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	W	D	LL/PL	Qu
1	FAT CLAY, black (OH)	TOPSOIL	6		1	SB				
	FAT CLAY, gray and brown mottled, rather stiff to medium to soft to medium, layers and laminations of silt (CH)	LAKE AGASSIZ DEPOSITS	9		2	SB				
			7		3	SB				
			4		4	SB				
			4		5	SB				
			5		6	SB				
14	SILTY SAND, fine grained, brown, wet, dense to very dense (SP-SM)	COARSE ALLUVIUM	23		7	SB				
			38		8	SB				
23	FAT CLAY, gray, soft (CH)	LAKE AGASSIZ DEPOSITS	4		9	SB				
			2		10	SB				

CONTINUED ON NEXT PAGE

LOG OF TEST BORING

JOB NO 53-1569 VERTICAL SCALE 1" = 4' BORING NO 11 Cont.

PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

DEPTH IN FEET	DESCRIPTION OF MATERIAL	GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	LABORATORY TESTS W	D	LL PL	Qu
35	FAT CLAY CONTINUED	LAKE AGASSIZ DEPOSITS CONTINUED	2		11	SB				
			2		12	SB				
			2		13	SB				
			2		14	SB				
			2		15	SB				
			2		16	SB				
			2		17	SB				

CONTINUED ON NEXT PAGE

LOG OF TEST BORING

JOB NO 53-1569 VERTICAL SCALE 1" = 4' BORING NO 11 Cont.
PROJECT OBSERVATION WELL INSTALLATION, FARGO LANDFILL, FARGO, ND

DEPTH IN FEET		GEOLOGIC ORIGIN	N	WL	SAMPLE NO	SAMPLE TYPE	LABORATORY TESTS W	D	LL/PL	Qu
70	FAT CLAY CONTINUED	LAKE AGASSIZ DEPOSITS CONTINUED	2		18	SB				
			3		19	SB				
			4		20	SB				
			5		21	SB				
86½	SILTY SAND, fine to medium grained, with gravel, gray, very dense (SP-SM)	COARSE ALLUVIUM	100/0.3		22	SB				
92½	END OF BORING									

WATER LEVEL MEASUREMENTS

DATE	TIME	SAMPLED DEPTH	CASING DEPTH	CAVE-IN DEPTH	BAILED DEPTHS	WATER LEVEL
Influenced by drilling fluid.					to	
					to	
					to	
					to	

START 4-28-83 COMPLETE 4-29-83
METHOD 6" FA 0-9½' @ 9:00
JW 9½-92½'
CREW CHIEF Miller

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SIEVE ANALYSIS TESTS

PROJECT OBSERVATION WELL INSTALLATION
FARGO LANDFILL, FARGO, ND

DATE 1-10-83

REPORTED TO Dr. Dixie Griffin

JOB NO. 53-1456

BORING NO.			6		
SAMPLE NO.			7		
DEPTH (ft)			15'-16'		
TYPE OF SAMPLE			SB		
CLASSIFICATION (ASTM: D 2487) Symbol			SP-SM		
Description			SILTY SAND, Fine Grained, Brown		
MECHANICAL ANALYSIS:					
Dry Weight of Total Sample (grams)			229		
Based on Total Sample					
% Finer Than	3"				
	2"				
	1"				
	3/4"				
	3/8"				
	# 4				
	# 10		100		
	# 40		99		
	# 100		22		
	# 200		8.3		

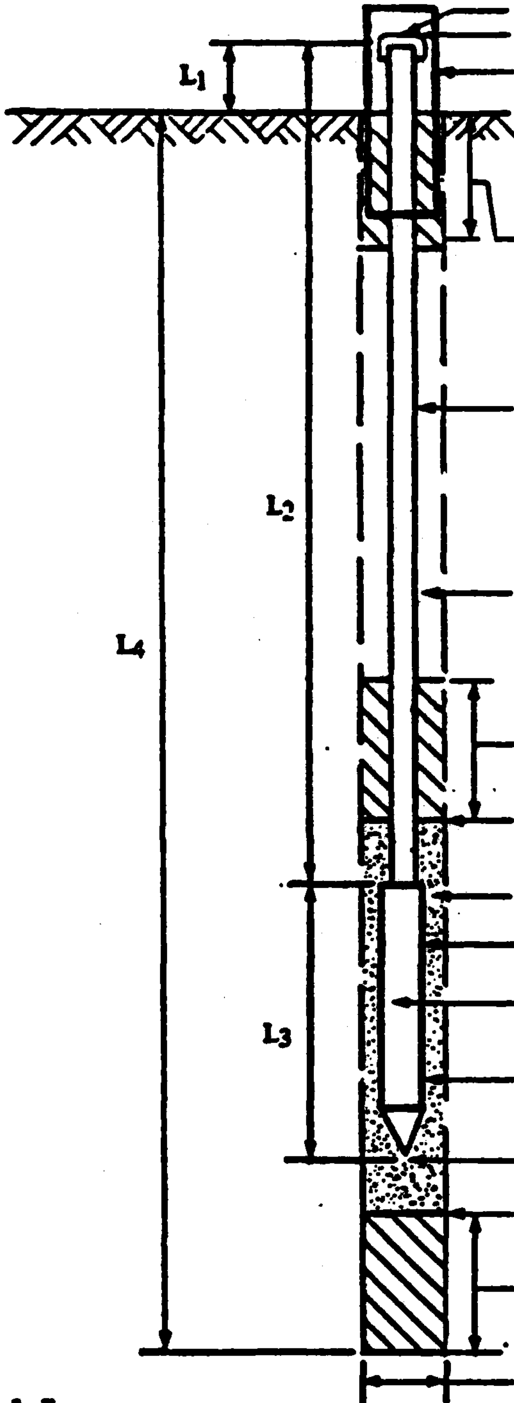
SL-46 (80-A)

twin city testing and engineering laboratory, inc.

INSTALLATION OF PIEZOMETER

JOB NO. 53-1456 PIEZOMETER NO. 1

GROUND ELEVATION AND DATUM 97.4'



VENTED CAP	
ELEVATION OF TOP OF RISER PIPE	99.1'
PROTECTIVE CASING	
Diameter and Type	4" Steel
Total Length	5'
Length Above Ground	2"
THICKNESS AND TYPE OF SEAL	Grout
DIAMETER AND TYPE OF RISER PIPE	2" PVC
TYPE OF BACKFILL AROUND RISER	Grout
THICKNESS AND TYPE OF SEAL	Grout
DEPTH TO TOP OF FILTER SAND	44'
TYPE OF FILTER AROUND SCREEN	Filter Sand
TYPE OF PIEZOMETER	PVC
SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.)	10 Slot
DIAMETER AND LENGTH OF SCREEN	2" x 5'
DEPTH TO BOTTOM OF PIEZOMETER	50'
DEPTH TO BOTTOM OF FILTER SAND	50'
THICKNESS AND TYPE OF SEAL	N/A
DIAMETER OF BOREHOLE	6"

L_1 = 1.7 FT

L_2 = 46.7' FT

L_3 = 5'. FT

L_4 = 50' FT

INSTALLATION COMPLETED:
Date 12-21-82 Time 11:30

PIEZOMETER WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL
12-22-82	9:30		11.3'
1-3-83	11:10		11.0'

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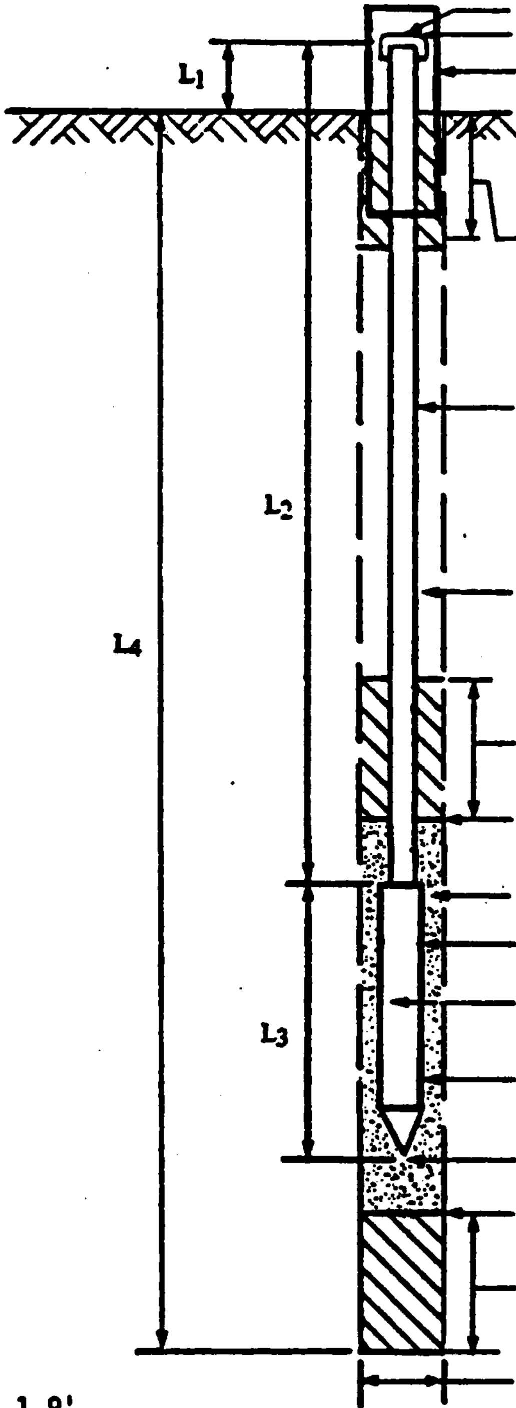
SE-24 (79-A)

JOB NO. 53-1456 PIEZOMETER NO. 2

GROUND ELEVATION AND DATUM 97.5'



VENTED CAP	
ELEVATION OF TOP OF RISER PIPE	99.4'
PROTECTIVE CASING	
Diameter and Type	4" Steel
Total Length	5'
Length Above Ground	2.2'
THICKNESS AND TYPE OF SEAL	Grout
DIAMETER AND TYPE OF RISER PIPE	2" PVC
TYPE OF BACKFILL AROUND RISER	Grout
THICKNESS AND TYPE OF SEAL	Grout
DEPTH TO TOP OF FILTER SAND	24'
TYPE OF FILTER AROUND SCREEN	Filter Sand
TYPE OF PIEZOMETER	PVC
SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.)	10 Slot
DIAMETER AND LENGTH OF SCREEN	2" x 5'
DEPTH TO BOTTOM OF PIEZOMETER	30'
DEPTH TO BOTTOM OF FILTER SAND	30'
THICKNESS AND TYPE OF SEAL	N/A
DIAMETER OF BOREHOLE	6"

L_1= 1.9' FT

L_2= 26.9' FT

L_3= 5' FT

L_4= 30' FT

INSTALLATION COMPLETED:
Date 12-21-82 Time 1:00

PIEZOMETER WATER LEVEL MEASUREMENTS			
DATE	TIME	BAILED DEPTHS	WATER LEVEL
12-22-82	9:30		9.2'
1-3-83	11:15		11.6'

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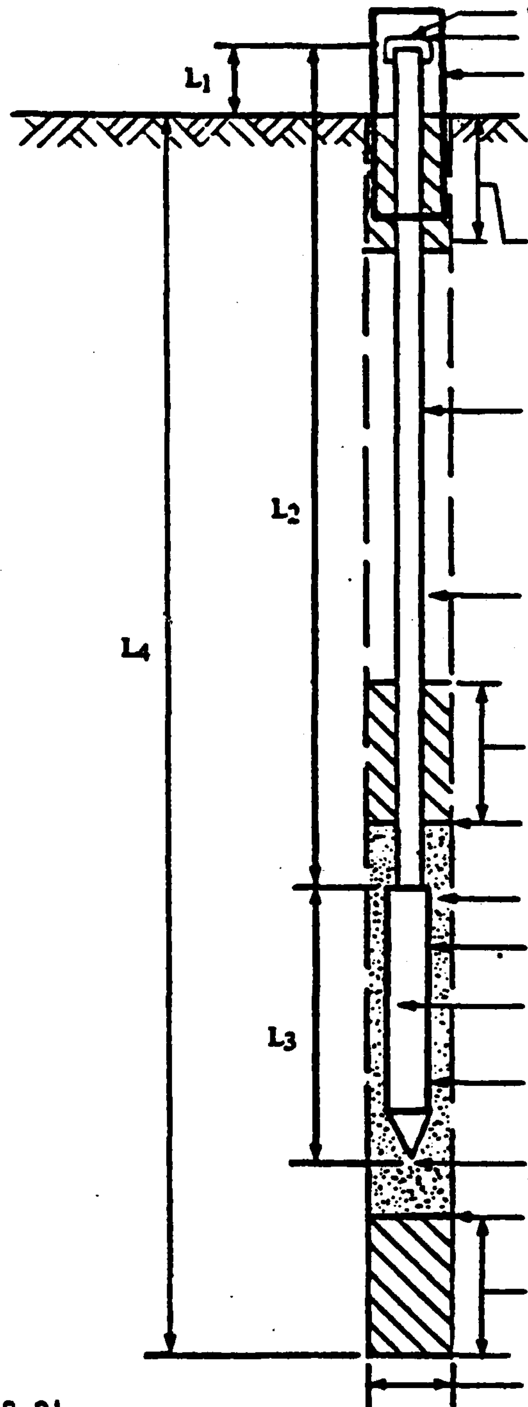
SE-24 (79-A)

INSTALLATION OF PIEZOMETER

JOB NO. 53-1456   PIEZOMETER NO. 3

GROUND ELEVATION AND DATUM 97.5'



VENTED CAP

ELEVATION OF TOP OF RISER PIPE: 100.3'

PROTECTIVE CASING
- Diameter and Type: 4" Steel
- Total Length: 5'
- Length Above Ground: 3'

THICKNESS AND TYPE OF SEAL: Grout

DIAMETER AND TYPE OF RISER PIPE: 2" PVC

TYPE OF BACKFILL AROUND RISER: Grout

THICKNESS AND TYPE OF SEAL: Grout

DEPTH TO TOP OF FILTER SAND: 12'

TYPE OF FILTER AROUND SCREEN: Filter Sand

TYPE OF PIEZOMETER: PVC

SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.): 10 Slot

DIAMETER AND LENGTH OF SCREEN: 2" x 10'

DEPTH TO BOTTOM OF PIEZOMETER: 23'

DEPTH TO BOTTOM OF FILTER SAND: 23'

THICKNESS AND TYPE OF SEAL: N/A

DIAMETER OF BOREHOLE: 6"

L_1 = 2.8' FT

L_2 = 15.8' FT

L_3 = 10' FT

L_4 = 23' FT

INSTALLATION COMPLETED:
Date 12-21-82 Time 2:30

PIEZOMETER WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL
12-22-82	9:30		9.3
1-3-83	11:17		11.7

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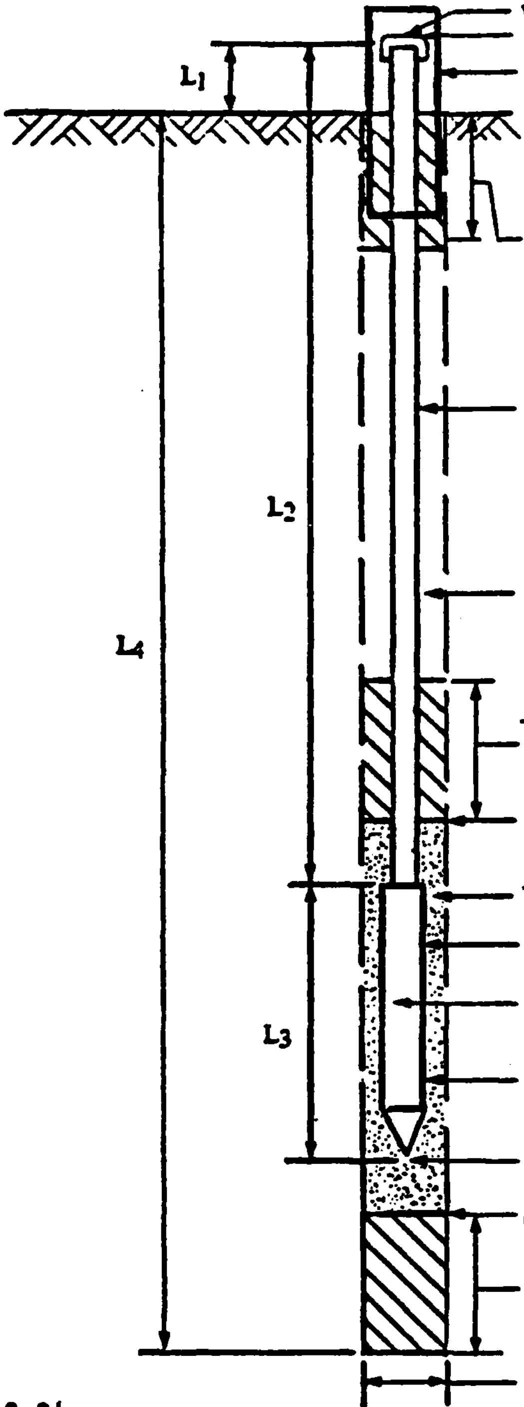
SE-24 (79-A)

INSTALLATION OF PIEZOMETER

JOB NO. 53-1456 PIEZOMETER NO. 4

GROUND ELEVATION AND DATUM 102.5'



VENTED CAP	
ELEVATION OF TOP OF RISER PIPE	104.8'
PROTECTIVE CASING	
Diameter and Type	4" Steel
Total Length	5'
Length Above Ground	3.2"
THICKNESS AND TYPE OF SEAL	Grout
DIAMETER AND TYPE OF RISER PIPE	2" PVC
TYPE OF BACKFILL AROUND RISER	Grout
THICKNESS AND TYPE OF SEAL	Grout
DEPTH TO TOP OF FILTER SAND	18'
TYPE OF FILTER AROUND SCREEN	Filter Sand
TYPE OF PIEZOMETER	PVC
SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.)	10 Slot
DIAMETER AND LENGTH OF SCREEN	2" x 5'
DEPTH TO BOTTOM OF PIEZOMETER	25'
DEPTH TO BOTTOM OF FILTER SAND	25'
THICKNESS AND TYPE OF SEAL	N/A
DIAMETER OF BOREHOLE	6"

L_1= 2.3' FT

L_2= 22.3' FT

L_3= 5' FT

L_4= 25' FT

INSTALLATION COMPLETED:
Date 12-22-82 Time 12:15

PIEZOMETER WATER LEVEL MEASUREMENTS			
DATE	TIME	BAILED DEPTHS	WATER LEVEL
12-22-82	12:00		23.0'
1-3-83	10:40		20.1'

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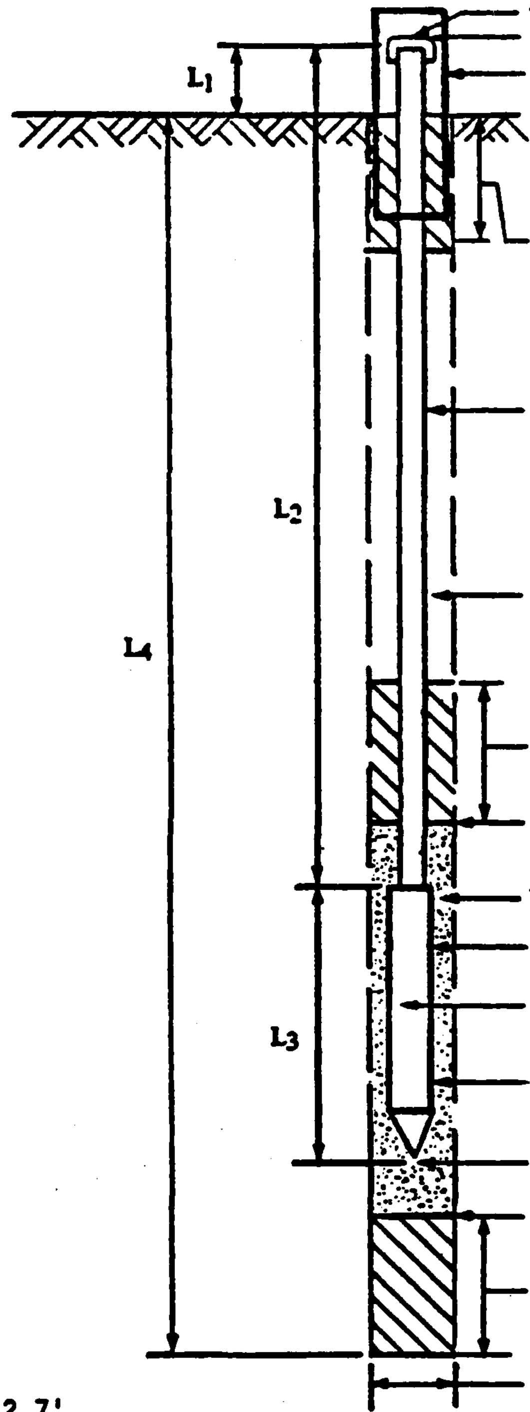
SE-24 (79-A)

INSTALLATION OF PIEZOMETER

JOB NO. 53-1456 PIEZOMETER NO. 5

GROUND ELEVATION AND DATUM 97.7'



VENTED CAP	
ELEVATION OF TOP OF RISER PIPE	100.4'
PROTECTIVE CASING	
Diameter and Type	4" Steel
Total Length	5'
Length Above Ground	3.2'
THICKNESS AND TYPE OF SEAL	Grout
DIAMETER AND TYPE OF RISER PIPE	2" PVC
TYPE OF BACKFILL AROUND RISER	Grout
THICKNESS AND TYPE OF SEAL	Grout
DEPTH TO TOP OF FILTER SAND	24'
TYPE OF FILTER AROUND SCREEN	Filter Sand
TYPE OF PIEZOMETER	PVC
SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.)	10 Slot
DIAMETER AND LENGTH OF SCREEN	2" x 5'
DEPTH TO BOTTOM OF PIEZOMETER	30'
DEPTH TO BOTTOM OF FILTER SAND	30'
THICKNESS AND TYPE OF SEAL	N/A
DIAMETER OF BOREHOLE	6"

L_1 = 2.7' FT

L_2 = 27.7' FT

L_3 = 5' FT

L_4 = 30' FT

INSTALLATION COMPLETED:
Date 12-22-82 Time 2:30

PIEZOMETER WATER LEVEL MEASUREMENTS			
DATE	TIME	BAILED DEPTHS	WATER LEVEL
12-22-82	2:30		28.0'
12-27-82			30.0'
1-3-83	11:00		30.0'

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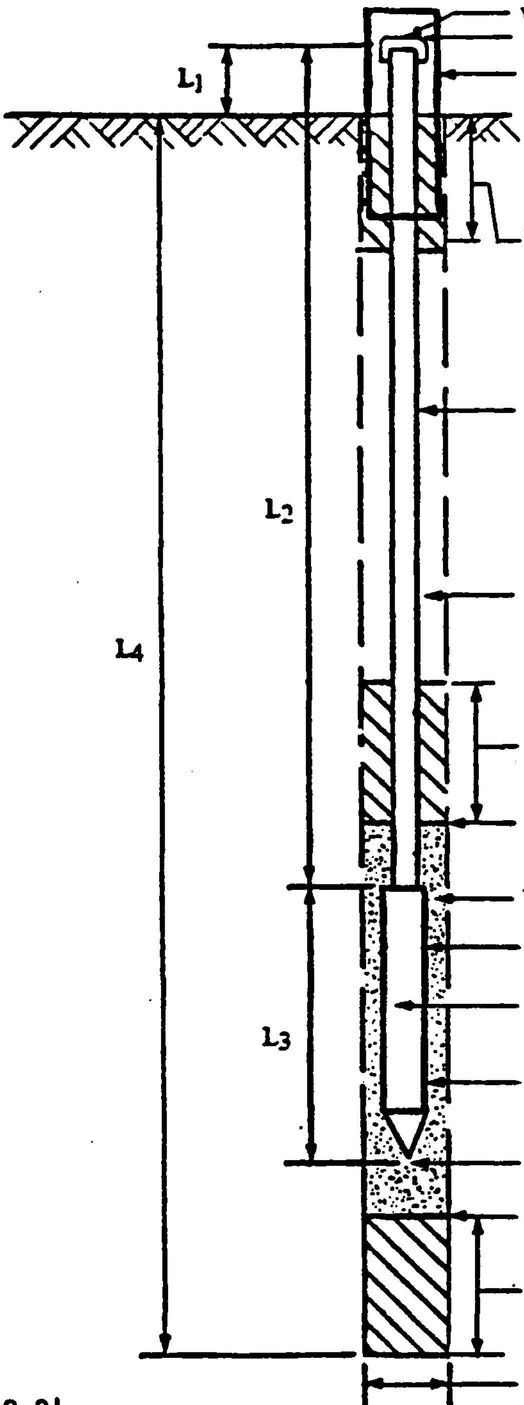
SE-24 (79-A)

INSTALLATION OF PIEZOMETER

JOB NO. 53-1456 PIEZOMETER NO. 6

GROUND ELEVATION AND DATUM 97.8'



- VENTED CAP
- ELEVATION OF TOP OF RISER PIPE: 100.6'
- PROTECTIVE CASING
  - Diameter and Type: 4" Steel
  - Total Length: 5'
  - Length Above Ground: 3'
- THICKNESS AND TYPE OF SEAL: Grout
- DIAMETER AND TYPE OF RISER PIPE: 2" PVC
- TYPE OF BACKFILL AROUND RISER: Grout
- THICKNESS AND TYPE OF SEAL: Grout
- DEPTH TO TOP OF FILTER SAND: 29'
- TYPE OF FILTER AROUND SCREEN: Filter Sand
- TYPE OF PIEZOMETER: PVC
- SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.): 10 Slot
- DIAMETER AND LENGTH OF SCREEN: 2" x 5'
- DEPTH TO BOTTOM OF PIEZOMETER: 35'
- DEPTH TO BOTTOM OF FILTER SAND: 35'
- THICKNESS AND TYPE OF SEAL: N/A
- DIAMETER OF BOREHOLE: 6"

L_1 = 2.8' FT

L_2 = 32.8' FT

L_3 = 5' FT

L_4 = 35' FT

INSTALLATION COMPLETED:
Date 12-27-82 Time 2:30

PIEZOMETER WATER LEVEL MEASUREMENTS			
DATE	TIME	BAILED DEPTHS	WATER LEVEL
1-3-83	10:30		15.0'

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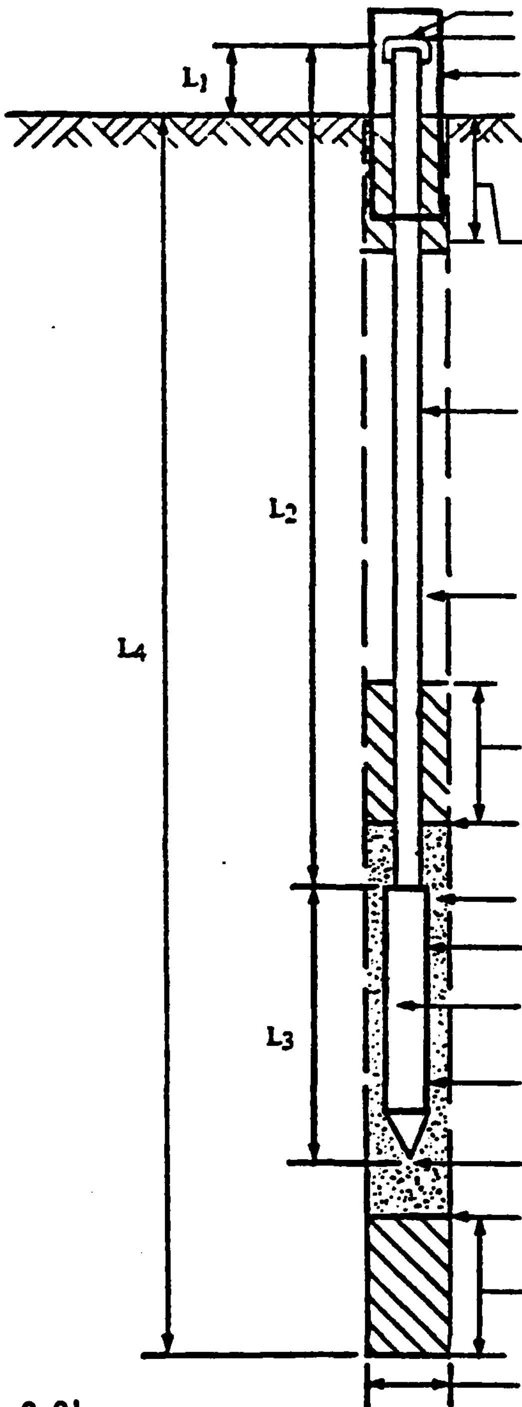
INSTALLATION OF PIEZOMETER

JOB NO. 53=1456

PIEZOMETER NO. 7

GROUND ELEVATION AND DATUM 101.8'



VENTED CAP

ELEVATION OF TOP OF RISER PIPE 104.7'

PROTECTIVE CASING
- Diameter and Type 4" Steel
- Total Length 5'
- Length Above Ground 3.2'

THICKNESS AND TYPE OF SEAL Grout

DIAMETER AND TYPE OF RISER PIPE 2" PVC

TYPE OF BACKFILL AROUND RISER Grout

THICKNESS AND TYPE OF SEAL Grout

DEPTH TO TOP OF FILTER SAND 29'

TYPE OF FILTER AROUND SCREEN Filter Sand

TYPE OF PIEZOMETER PVC

SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.) 10 Slot

DIAMETER AND LENGTH OF SCREEN 2" x 5'

DEPTH TO BOTTOM OF PIEZOMETER 35'

DEPTH TO BOTTOM OF FILTER SAND 35

THICKNESS AND TYPE OF SEAL N/A

DIAMETER OF BOREHOLE 6"

L_1 = 2.9' FT

L_2 = 32.9' FT

L_3 = 5' FT

L_4 = 35' FT

INSTALLATION COMPLETED:
Date 12-28-82 Time 11:20

PIEZOMETER WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL
1-3-83	9:30		18.6'

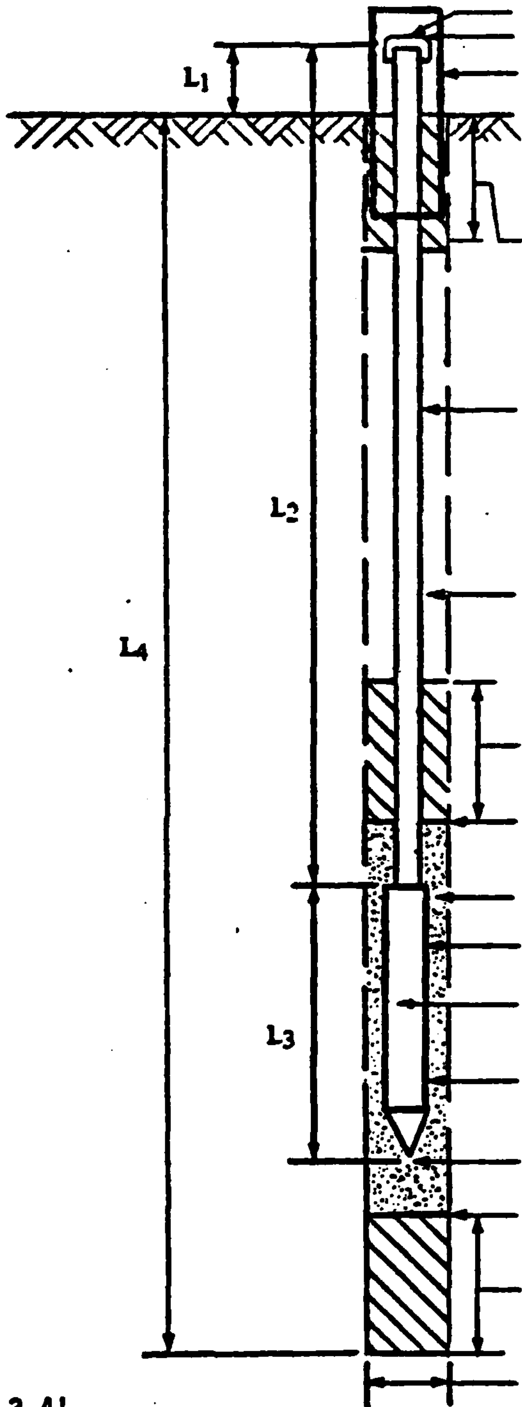
twin city testing and engineering laboratory, inc.

SE-24(79-A)

INSTALLATION OF PIEZOMETER

JOB NO. 53-1456 PIEZOMETER NO. 8

GROUND ELEVATION AND DATUM 97.7'



VENTED CAP	
ELEVATION OF TOP OF RISER PIPE	101.1'
PROTECTIVE CASING	
Diameter and Type	4" Steel
Total Length	5'
Length Above Ground	3.6'
THICKNESS AND TYPE OF SEAL	Grout
DIAMETER AND TYPE OF RISER PIPE	2" PVC
TYPE OF BACKFILL AROUND RISER	Grout
THICKNESS AND TYPE OF SEAL	Grout
DEPTH TO TOP OF FILTER SAND	28'
TYPE OF FILTER AROUND SCREEN	Filter Sand
TYPE OF PIEZOMETER	PVC
SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.)	10 Slot
DIAMETER AND LENGTH OF SCREEN	2" x 5'
DEPTH TO BOTTOM OF PIEZOMETER	35'
DEPTH TO BOTTOM OF FILTER SAND	35'
THICKNESS AND TYPE OF SEAL	N/A
DIAMETER OF BOREHOLE	6"

L_1 = 3.4' FT

L_2 = 33.4' FT

L_3 = 5' FT

L_4 = 35' FT

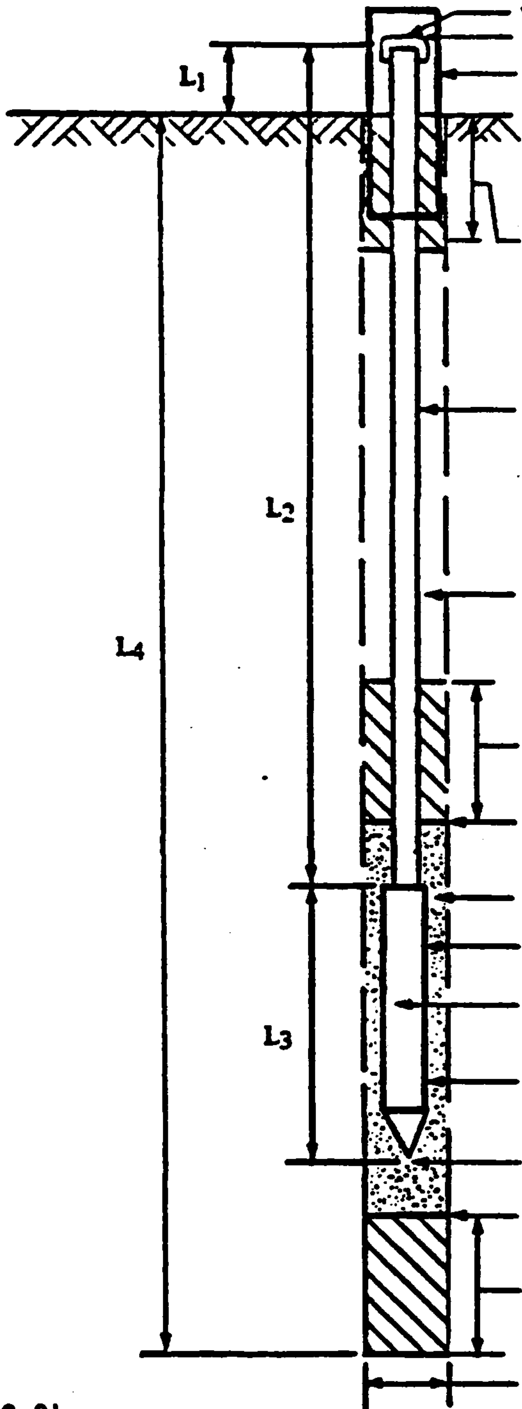
INSTALLATION COMPLETED:
Date 12-30-82 Time 3:30

PIEZOMETER WATER LEVEL MEASUREMENTS			
DATE	TIME	BAILED DEPTHS	WATER LEVEL
12-30-82	3:00		35'
1-3-83	9:00		19.2'

INSTALLATION OF PIEZOMETER

JOB NO. 53-1456 PIEZOMETER NO. 9

GROUND ELEVATION AND DATUM 102.5'



VENTED CAP	
ELEVATION OF TOP OF RISER PIPE	104.5'.
PROTECTIVE CASING	
Diameter and Type	4" Steel
Total Length	5'
Length Above Ground	2.2'
THICKNESS AND TYPE OF SEAL	Grout
DIAMETER AND TYPE OF RISER PIPE	2" PVC
TYPE OF BACKFILL AROUND RISER	Grout
THICKNESS AND TYPE OF SEAL	Grout
DEPTH TO TOP OF FILTER SAND	23'
TYPE OF FILTER AROUND SCREEN	Filter Sand
TYPE OF PIEZOMETER	PVC
SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.)	10 Slot
DIAMETER AND LENGTH OF SCREEN	2" x 5'
DEPTH TO BOTTOM OF PIEZOMETER	30'
DEPTH TO BOTTOM OF FILTER SAND	30'
THICKNESS AND TYPE OF SEAL	N/A
DIAMETER OF BOREHOLE	6"

L_1 = 2.0' FT

L_2 = 27' FT

L_3 = 5' FT

L_4 = 30' FT

INSTALLATION COMPLETED:
Date 12-29-82 Time 10:00

PIEZOMETER WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL
1-3-83	9:45		17.2'

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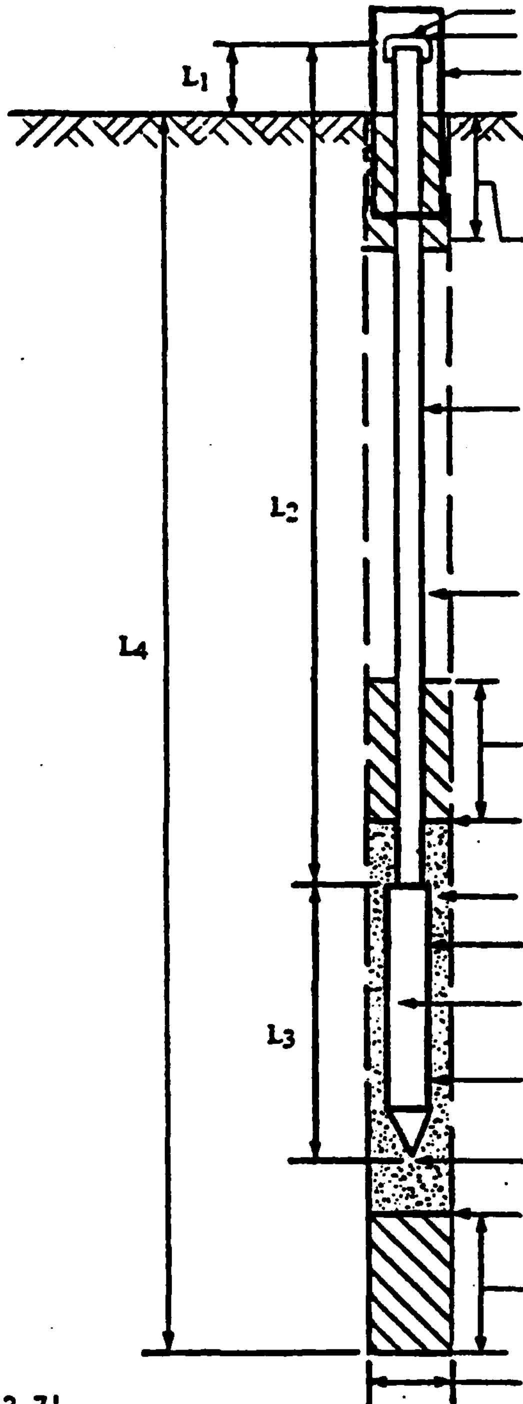
INSTALLATION OF PIEZOMETER

JOB NO. 53-1456 PIEZOMETER NO. 10

GROUND ELEVATION AND DATUM 95.0'



VENTED CAP	
ELEVATION OF TOP OF RISER PIPE	98.7'
PROTECTIVE CASING	
Diameter and Type	4" Steel
Total Length	5'
Length Above Ground	4'
THICKNESS AND TYPE OF SEAL	Grout
DIAMETER AND TYPE OF RISER PIPE	2" PVC
TYPE OF BACKFILL AROUND RISER	Grout
THICKNESS AND TYPE OF SEAL	Grout
DEPTH TO TOP OF FILTER SAND	29'
TYPE OF FILTER AROUND SCREEN	Filter Sand
TYPE OF PIEZOMETER	PVC
SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.)	10 Slot
DIAMETER AND LENGTH OF SCREEN	2" x 5'
DEPTH TO BOTTOM OF PIEZOMETER	35'
DEPTH TO BOTTOM OF FILTER SAND	35'
THICKNESS AND TYPE OF SEAL	N/A
DIAMETER OF BOREHOLE	6"

L_1 = 3.7' FT

L_2 = 33.7' FT

L_3 = 5' FT

L_4 = 35' FT

INSTALLATION COMPLETED:
Date 1-4-83 Time 3:00

PIEZOMETER WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL
1-4-83	3:00		30.3

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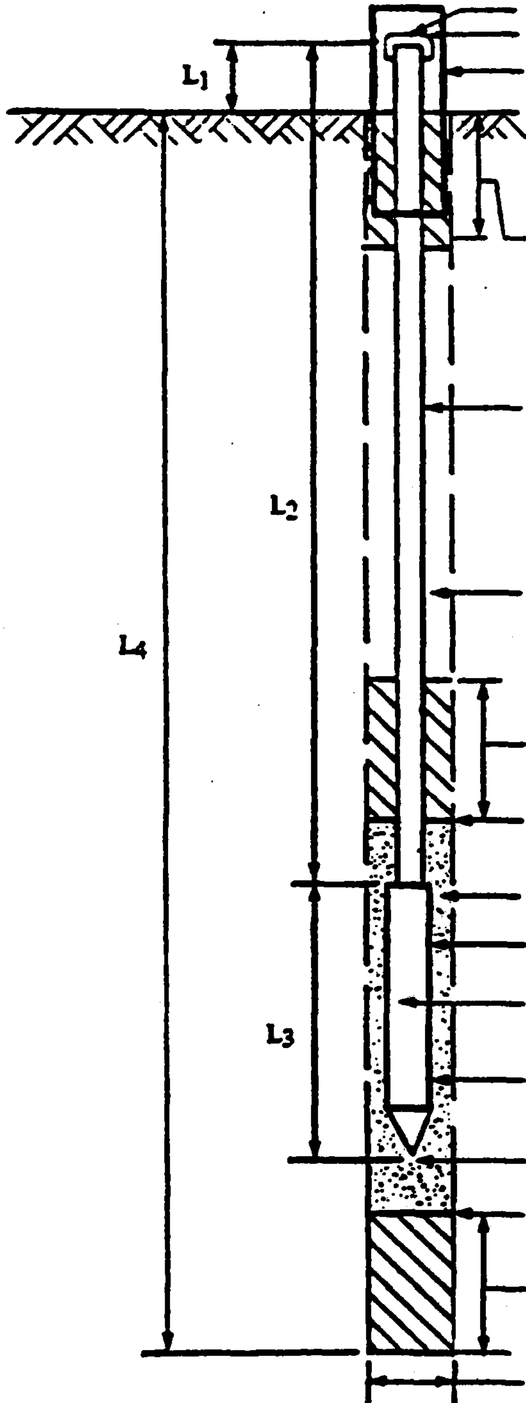
INSTALLATION OF PIEZOMETER

JOB NO. 53-1569 PIEZOMETER NO. 11

GROUND ELEVATION AND DATUM 96.7'



VENTED CAP	
ELEVATION OF TOP OF RISER PIPE	98.2'
PROTECTIVE CASING	
Diameter and Type	4" Steel
Total Length	5'
Length Above Ground	4'
THICKNESS AND TYPE OF SEAL	Grout
DIAMETER AND TYPE OF RISER PIPE	2" PVC
TYPE OF BACKFILL AROUND RISER	Grout
THICKNESS AND TYPE OF SEAL	Grout
DEPTH TO TOP OF FILTER SAND	85'
TYPE OF FILTER AROUND SCREEN	Filter Sand
TYPE OF PIEZOMETER	PVC
SCREEN GAUGE OR SIZE OF OPENINGS (SLOT NO.)	10 Slot
DIAMETER AND LENGTH OF SCREEN	2" x 5'
DEPTH TO BOTTOM OF PIEZOMETER	92.5'
DEPTH TO BOTTOM OF FILTER SAND	92.5'
THICKNESS AND TYPE OF SEAL	N/A
DIAMETER OF BOREHOLE	4"

L_1 = 1.5 FT

L_2 = 89 FT

L_3 = 5 FT

L_4 = 92.5 FT

INSTALLATION COMPLETED:
Date 6-29-83 Time 5:00

PIEZOMETER WATER LEVEL MEASUREMENTS

DATE	TIME	BAILED DEPTHS	WATER LEVEL

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END

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